



Spinal Fusion

Basic Concepts and Complications

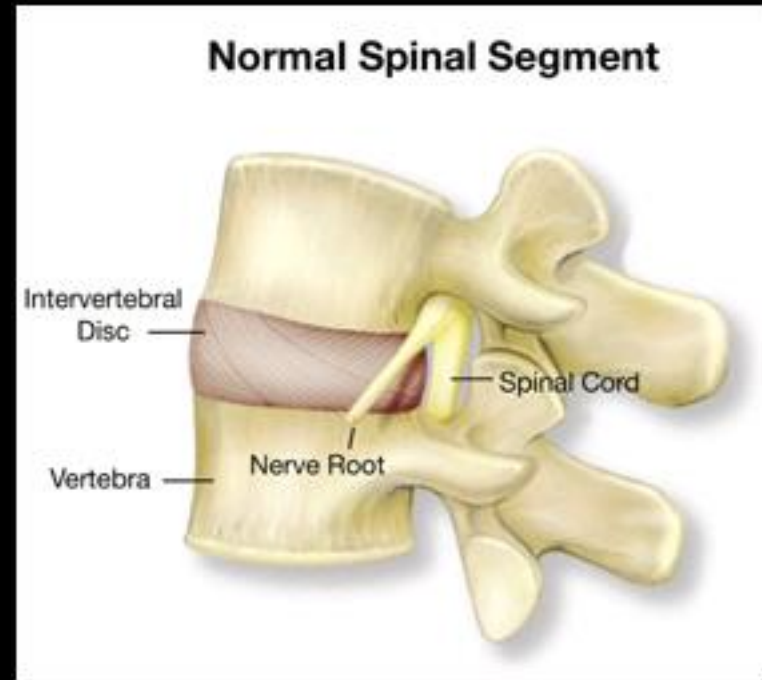
Dwight Lee

Early spinal fusion

- Successful spinal fusion procedures appeared in the medical literature in the early 20th century
 - Tuberculous spondylitis
 - Misaligned spines (spondylolisthesis)
- Early surgeries relied upon extended bracing for solid fusion to occur with considerably long convalescence periods
- High failure rate
 - Harvested autogenous bone graft
 - Lack of structural integrity and the undesirable side effects of the harvesting procedure
 - Either bone graft or posterior pedicle screws

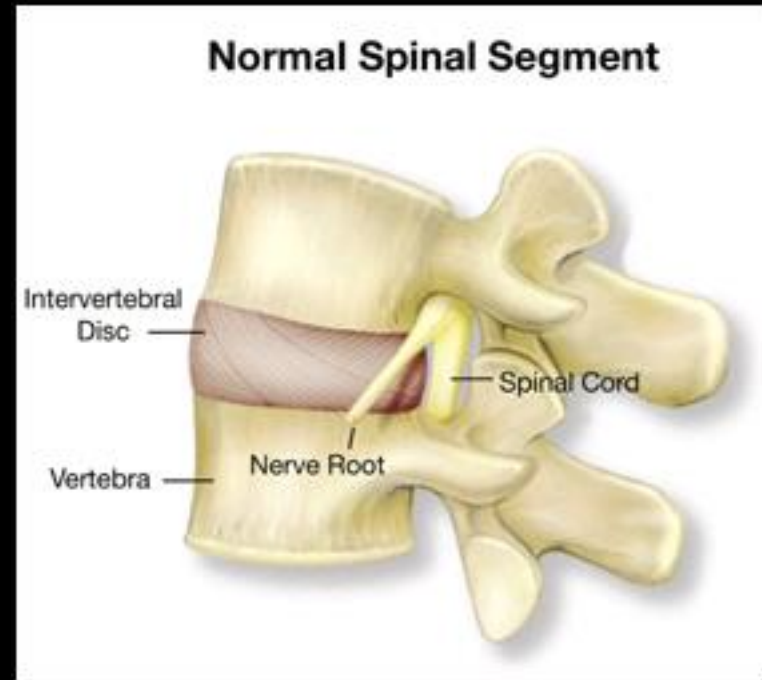
Spine

- Complex structure that transmits loads from the upper body through the pelvis into the lower extremities.
- Spinal motion segment is the smallest functional unit addressing spinal biomechanics.
 - Two adjacent vertebrae
 - Intervertebral disc
 - Ligaments
 - Apophyseal joints



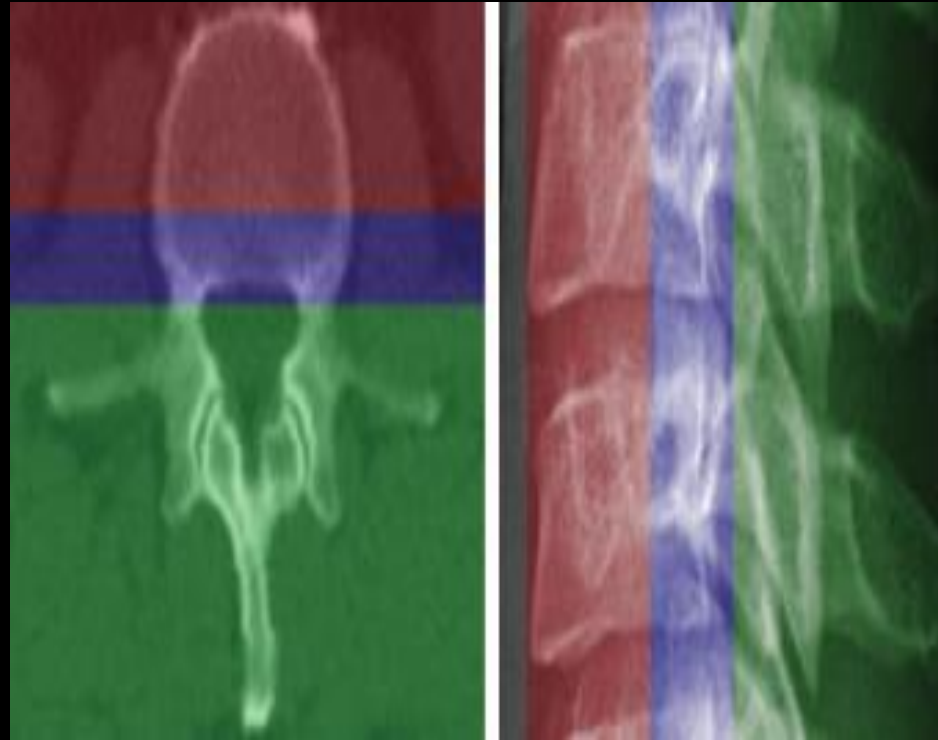
Spine

- Most of the motion in the lumbar spine is at the L4-L5 level, and to a lesser extent at L3-L4.



Spine

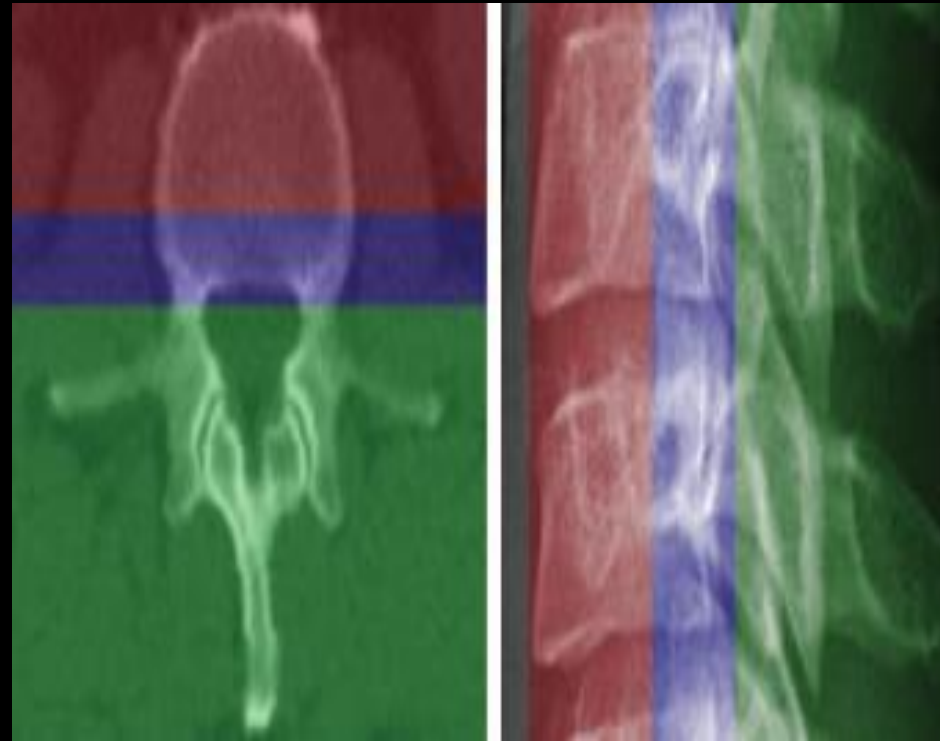
- Denis's spinal model is widely employed by spinal surgeons to address genuine native gross spinal stability
- Two of the three spinal columns must be anatomically intact for functional stability
- Violation of more than one column by trauma, infection, tumor, degenerative change, or surgical approach will necessitate spinal instrumentation



Denis's spinal model

Anterior

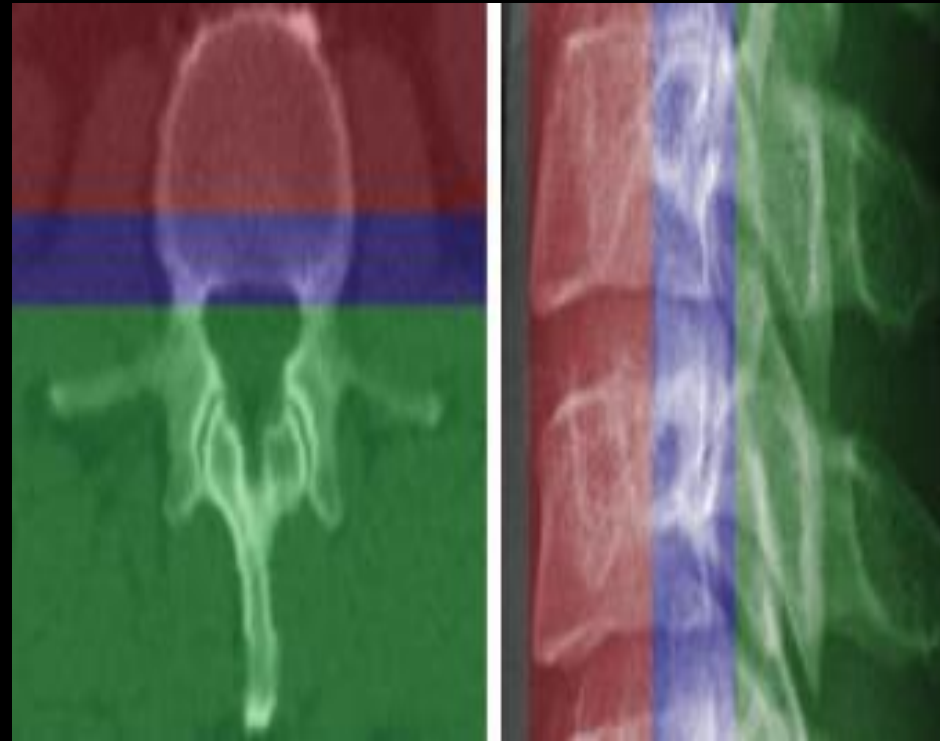
- ALL, anterior 2/3 of the vertebral body and annulus fibrosus
- Function
 - Bears axial load
 - Resist extension



Denis's spinal model

Middle

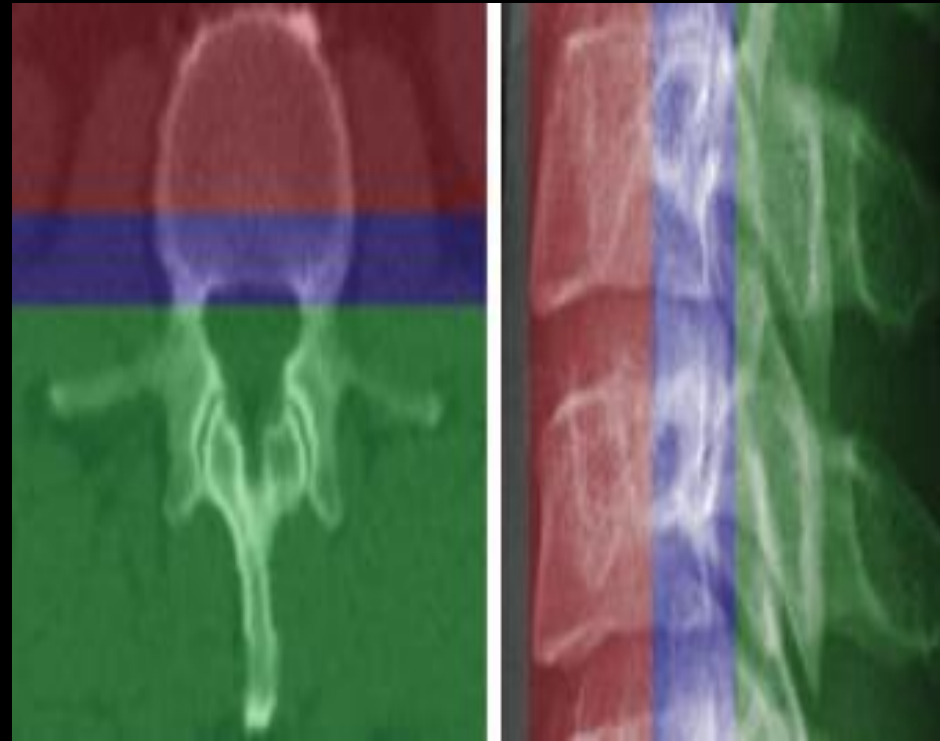
- Posterior 2/3 of the vertebral body, annulus fibrosus, nucleus pulposus and PLL
- Function
 - Resist flexion
 - Shares in axial loading



Denis's spinal model

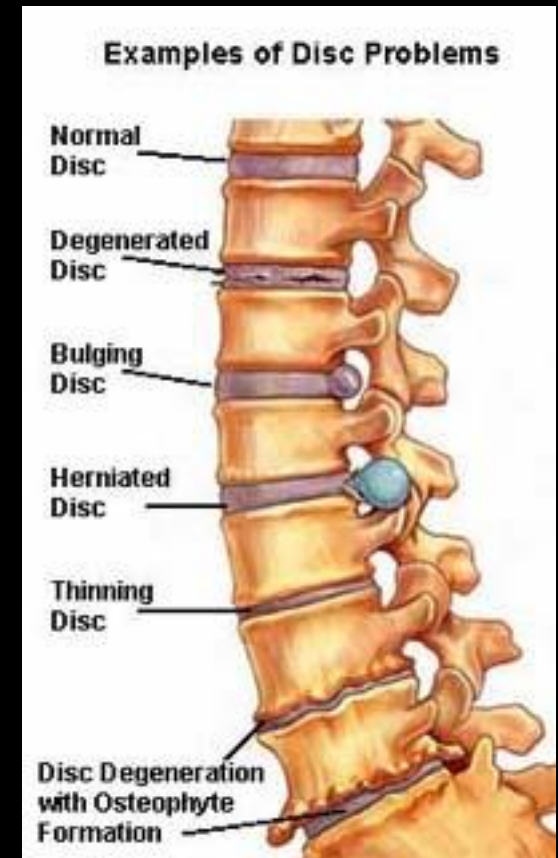
Posterior

- Posterior vertebral arch elements
- Function
 - Spinal stability during rotational movements
 - Resist flexion



Reasons for spinal fusion

- Spinal stability restoration
- Deformity correction
- Spinal-motion segment height restoration
- Pain relief
- Management
 - Scoliosis and other spinal deformities
 - Spinal degenerative disease
 - Trauma
 - Instability
 - Infection
 - Neoplasm



Goals of spinal fusion

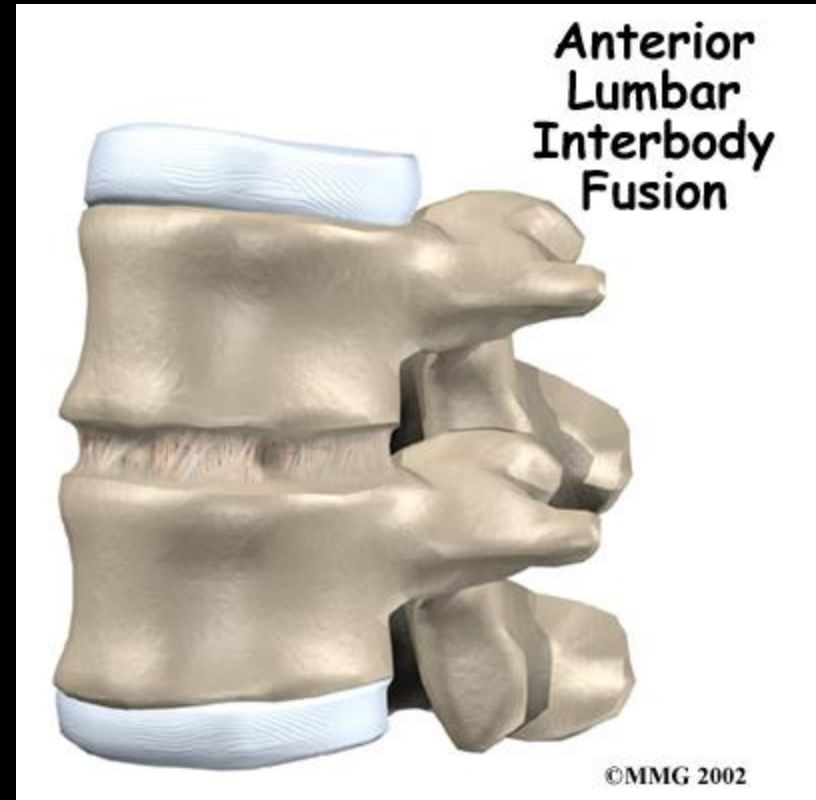
- Restore and maintain disk space height and normal sagittal contours
- Increase the stability of the operated segment or segments
 - Stretching the annulus and supporting ligaments via distraction of the disk space aka “ligamentotaxis” and provide a biomechanically stable construct that will limit motion and permit fusion to develop
- Maintain alignment of spinal segments by sharing the loads acting on the spine, usually until solid biological fusion occurs
 - Instrument failure occurs if solid bony fusion is not achieved

Interbody Fusion Approach

1. Posterior Lumbar Interbody Fusion (PLIF)
2. Transforaminal Lumbar Interbody Fusion (TLIF)
3. Anterior Lumbar Interbody Fusion (ALIF) -Anterior approach with an incision in the abdomen
4. Anterior Cervical Disc Fusion (ACDF)
5. Lateral lumbar interbody fusion

Terminology

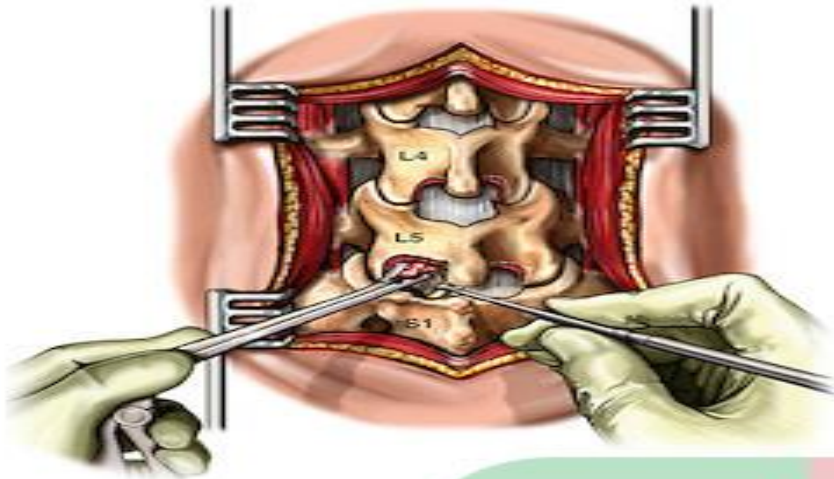
- Interbody Fusion
 - Bone graft is placed in between the vertebral bodies where the disc usually lies
 - Disc has to be completely removed and endplates cleaned prior to placement of the graft.



Posterior Fusion

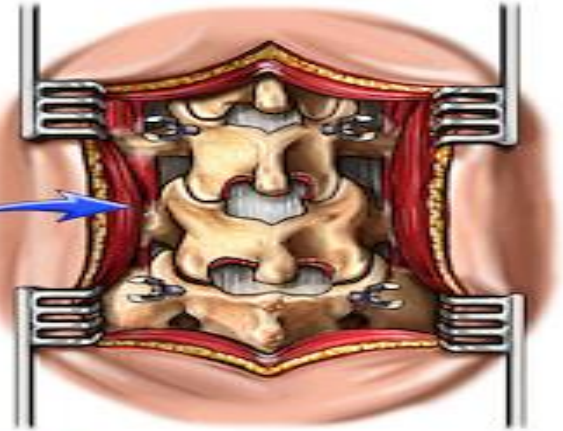
- Different combinations of plates or rods with hook/wire/pedicle screw systems form posterior spinal construct devices for different spinal levels
- Used when posterior decompression is required in addition to fusion as in degenerative spinal disease or spinal stenosis
 - More common in dorsal and lumbar regions
 - Easier and adequately visualizes neural elements
 - Avoids the high-risk of the anterior approach in these regions
 - Avoided in the cervical region for cord manipulation risks at that level
- Rods are commonly used for long segment spinal fixations
- Plates are favored for short segment fixations

Posterior Gutter Fusion



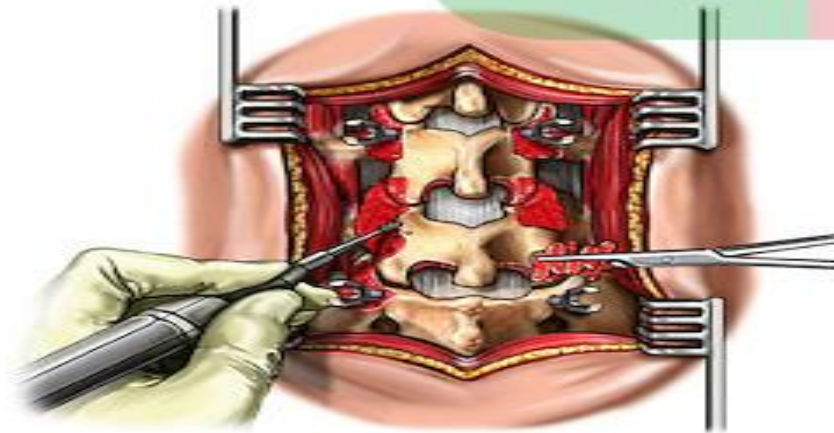
A. PORTIONS OF THE LAMINAE ARE REMOVED FROM L4-5 AND L5-S1. THE HERNIATED DISC MATERIAL IS THEN REMOVED FROM BOTH SPACES.

PEDICLE SCREWS

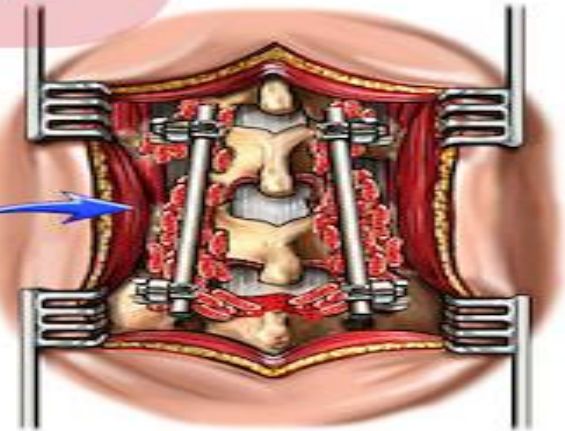


B. PEDICLE SCREWS ARE PLACED AT L4 AND S1.

Doctor Stock



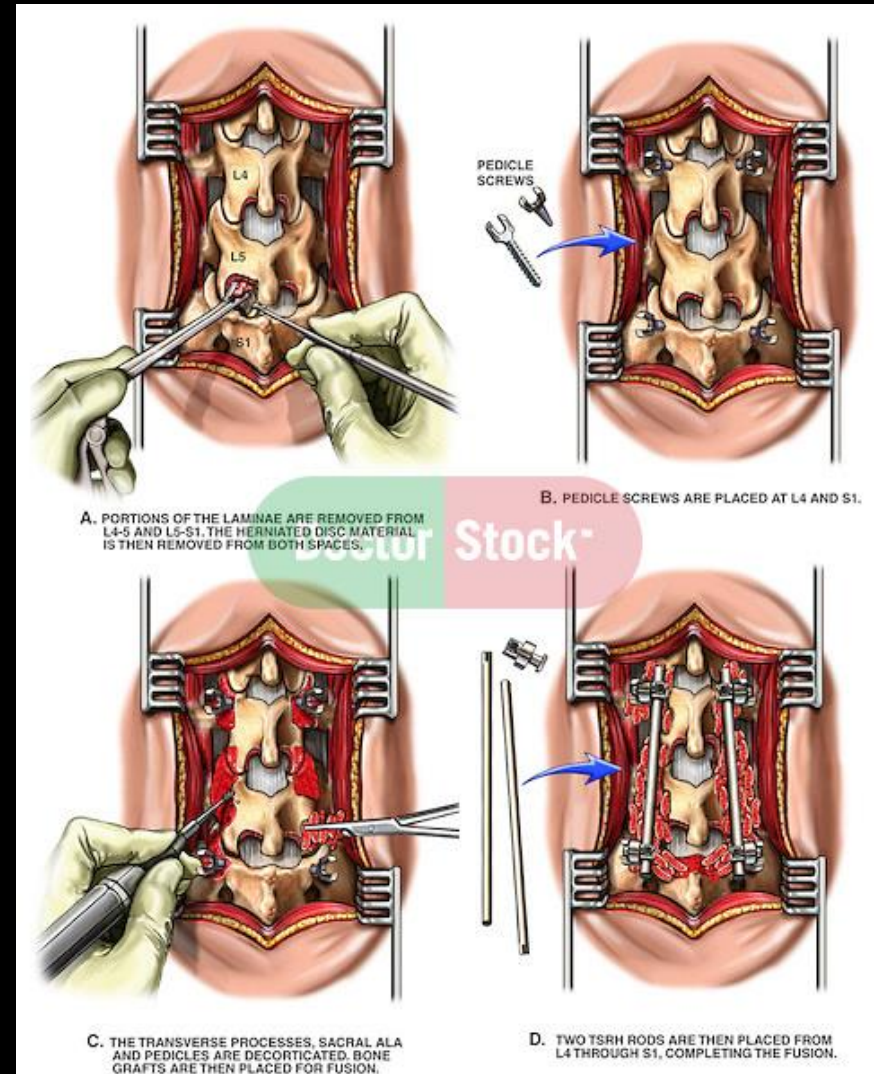
C. THE TRANSVERSE PROCESSES, SACRAL ALA AND PEDICLES ARE DECORTICATED. BONE GRAFTS ARE THEN PLACED FOR FUSION.



D. TWO TSRH RODS ARE THEN PLACED FROM L4 THROUGH S1, COMPLETING THE FUSION.

Posterior Lumbar Interbody Fusion

- To obtain access to the disk space, the surgeon must retract the thecal sac and nerve roots medially.
- Difficult to place sufficiently large devices to gain stability and provide ligamentotaxis without injuring the nerve roots



Transforaminal Lumbar Interbody Fusion

- Transforaminal lumbar interbody fusion is a modified posterior approach that permits foraminal decompression
 - Removes the pars interarticularis and facet joint unilaterally
 - Disk space is approached from the posterolateral direction in the zone between the transversing nerve root and the superior exiting nerve root
 - Disc material is removed.
 - A spacer or interbody cage that is filled with bone graft is placed into the disc space to maintain the disc height.
 - Additional bone is placed in the lateral (side) gutters of the vertebra and the disc space.
 - Minimal tissue damage
 - Minimal blood loss
 - Small incisions and scars
 - Minimal post-operative discomfort
 - Relatively quick recovery time and return to normal function.

Transforaminal Lumbar Interbody Fusion

Orientation

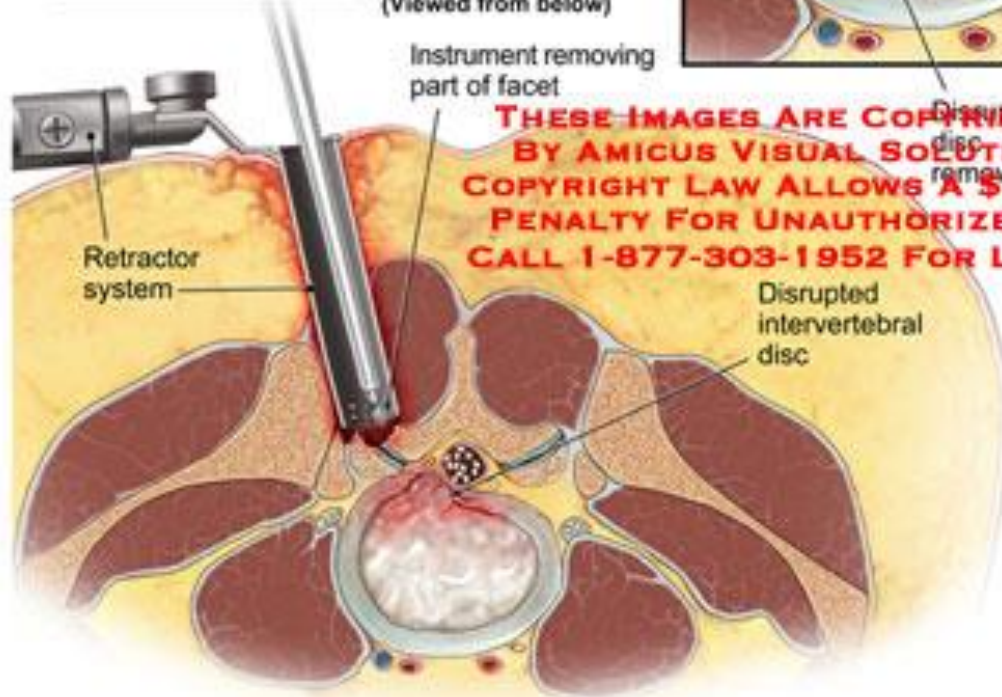


Minimally Invasive Approach Through Small Incision (Viewed from below)

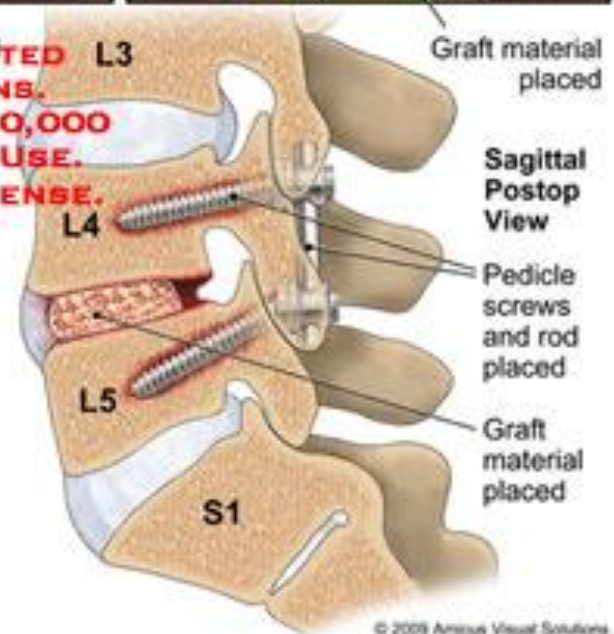
Microdiscectomy



Interbody Fusion



THESE IMAGES ARE COPYRIGHTED BY AMICUS VISUAL SOLUTIONS. COPYRIGHT LAW ALLOWS A \$150,000 PENALTY FOR UNAUTHORIZED USE. CALL 1-877-303-1952 FOR LICENSE.



© 2008 Amicus Visual Solutions

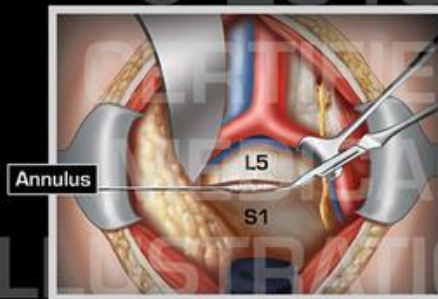
Anterior Lumbar Interbody Fusion

ANTERIOR LUMBAR DISCECTOMY & FUSION OF L5-S1

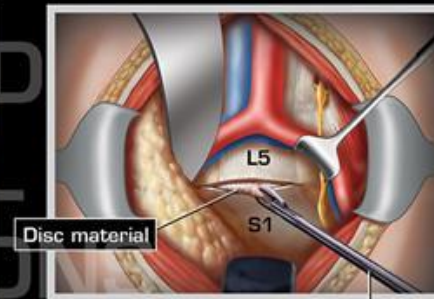
A. Incision Site of Lower Abdomen



B. Retroperitoneal Exposure & Annulotomy of L5-S1

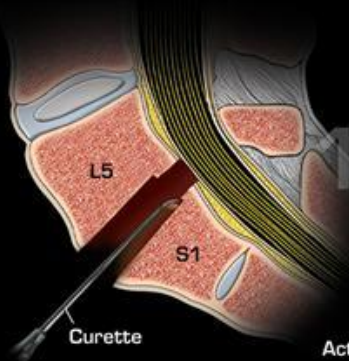


C. Complete Radical Discectomy at L5-S1

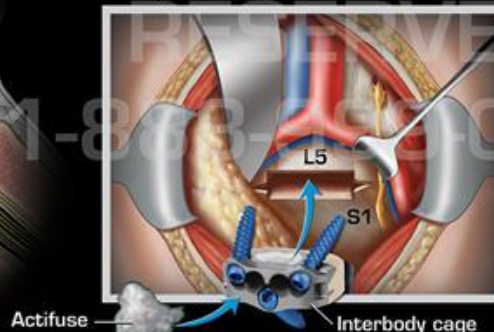


Pituitary forceps

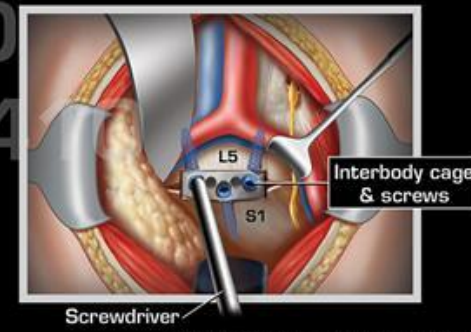
D. Decortication of End Plate at L5-S1



E. Impaction of Interbody Cage with Actifuse into L5-S1 Space



F. Anterior Fixation of L5-S1 with Screws

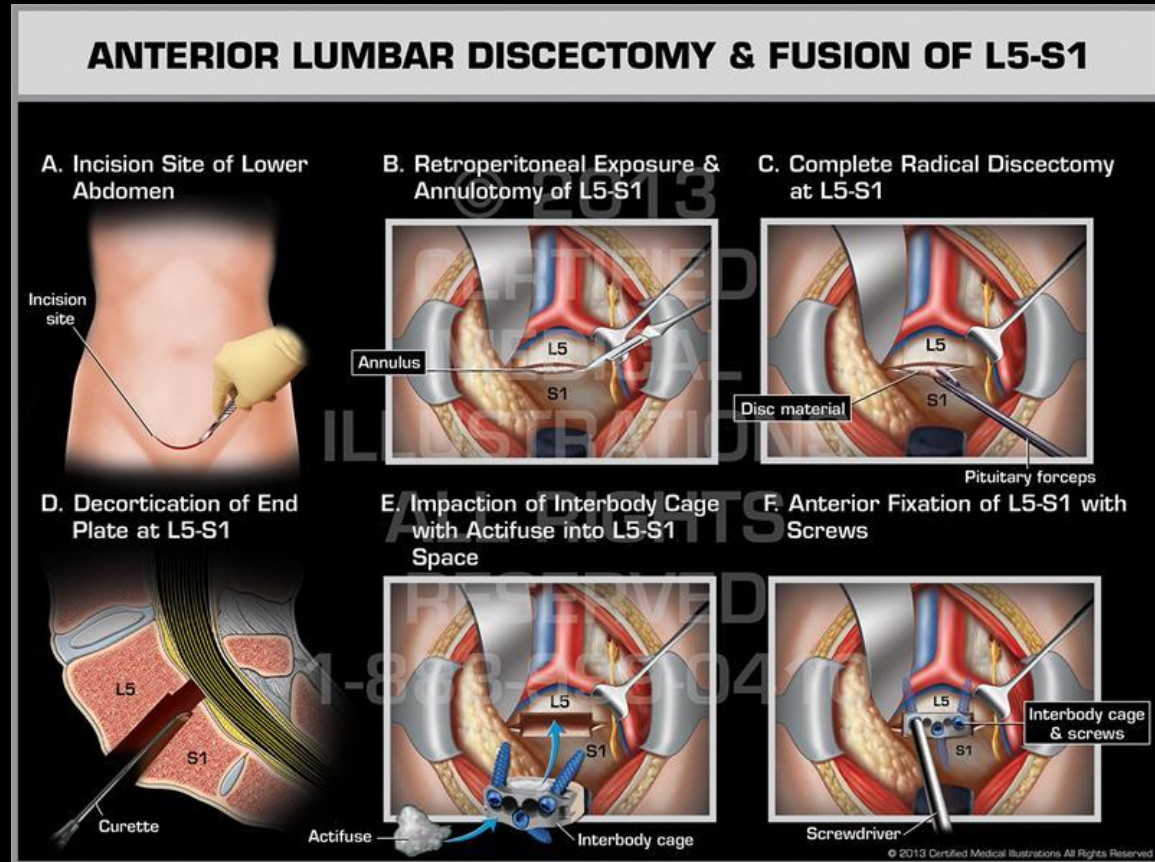


© 2013 Certified Medical Illustrations All Rights Reserved

Anterior Lumbar Interbody Fusion

ALIF

- Alone can be sufficient.
 - One level degenerative disc disease where there is a lot of disc space
 - Presence of facet joint disease contra-indicates
- Performed with posterior approach to provide additional stability
 - "tall" disc
 - Instability



Anterior Fusion - ALIF

- Back muscles and nerves remain undisturbed while retaining all posterior stabilizing structures and avoiding nerve root retraction and epidural scarring.
- Permits placement of optimal-sized devices to provide stability and ultimately to facilitate fusion
- Another advantage is that placing the bone graft in the front of the spine places it in compression, and bone in compression tends to fuse better.
- For males, another risk unique to this approach is that approaching the L5-S1 (lumbar segment 5 and sacral segment 1) disc space from the front has a risk of creating a condition known as retrograde ejaculation.
 - Very small nerves directly over the disc interspace that control a valve that causes the ejaculate to be expelled outward during intercourse.

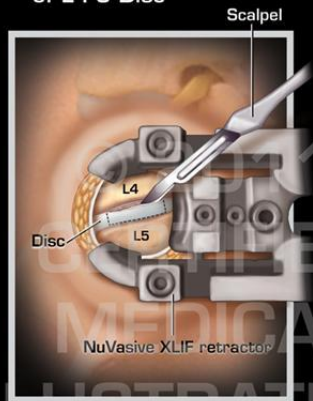
Xtreme Lateral Interbody Fusion

LATERAL LUMBAR INTERBODY FUSION

A. Left Incision
Over Iliac
Crest



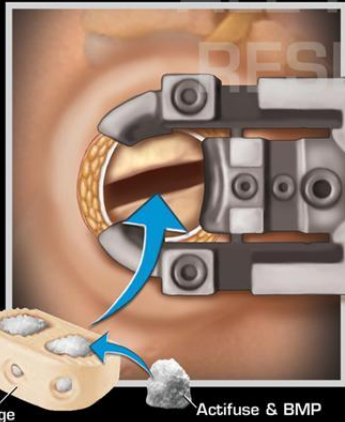
B. Left Exposure & Incision
of L4-5 Disc



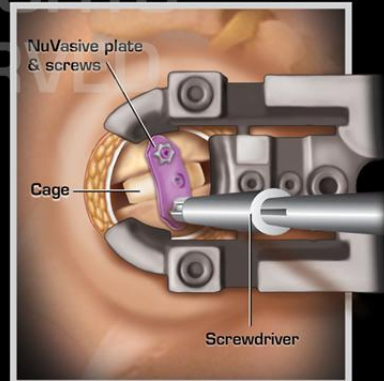
C. Discectomy at L4-5



D. Insertion of Cage with Graft
into L4-5 Space



E. Fixation of L4, L5 with Plate
& Screws



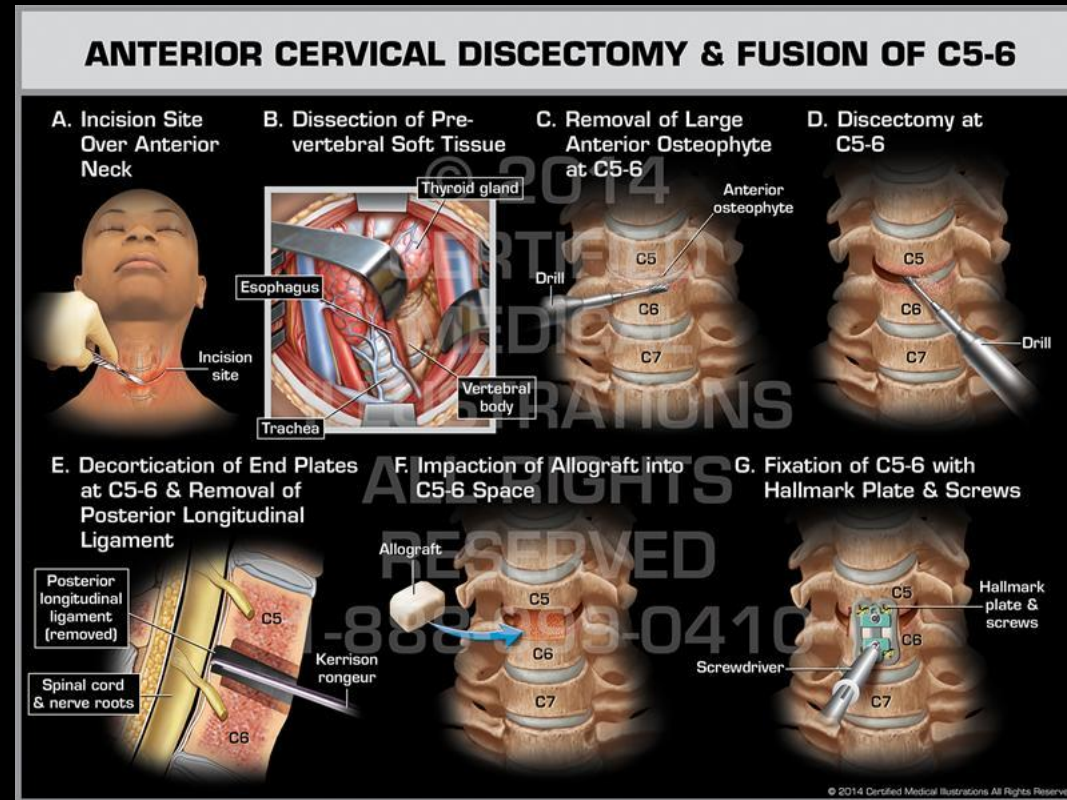
Advantages

- Minimal tissue damage
- Minimal blood loss
- Small incisions and scars
- Minimal post-operative discomfort
- Relatively quick recovery time and return to normal function.

www.certifiedmedicalillustrations.com/

Anterior Fusion - ACDF

- ACDF
 - Commonly known as anterior cervical discectomy and fusion or ACDF
 - Approach is favored, risk of cord manipulation associated with a posterior approach at this level
 - Implants used posteriorly in the thoracic and lumbar regions are too large imparting greater traction forces that are not needed in the smaller cervical spine

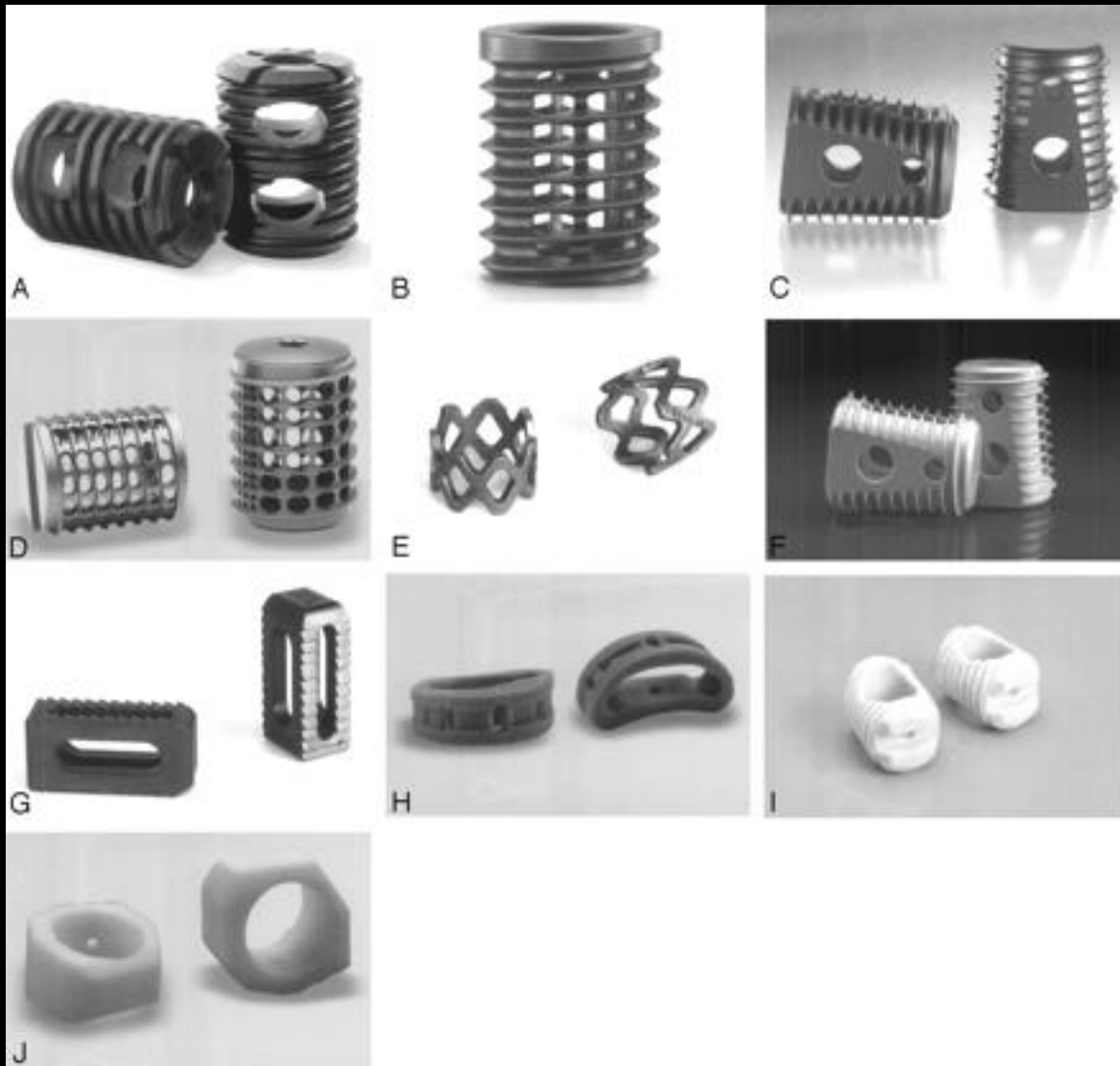


INTERBODY GRAFTS

Interbody grafts

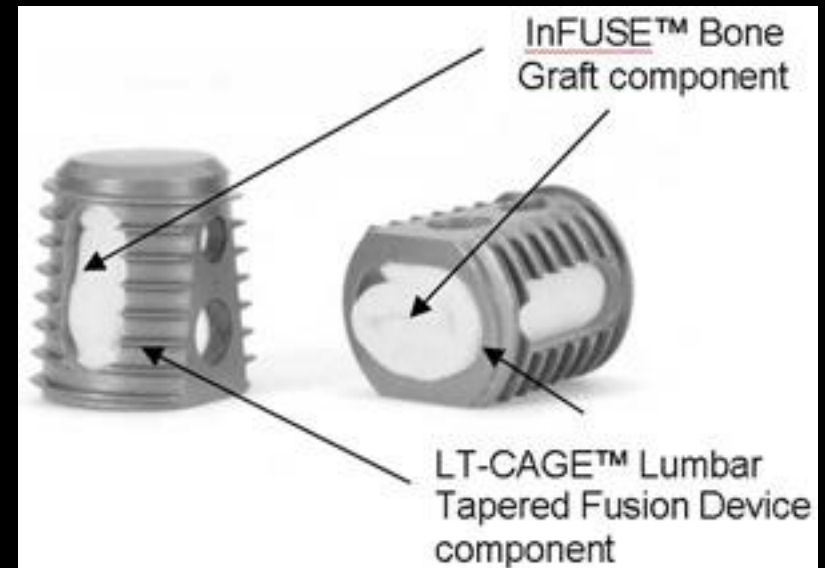
- Inter-body fusion may be carried out with cortical bone and autogenous grafting or with inter-body fusion cages
- Implanted hardware exists solely to provide short-term stability while fusion develops





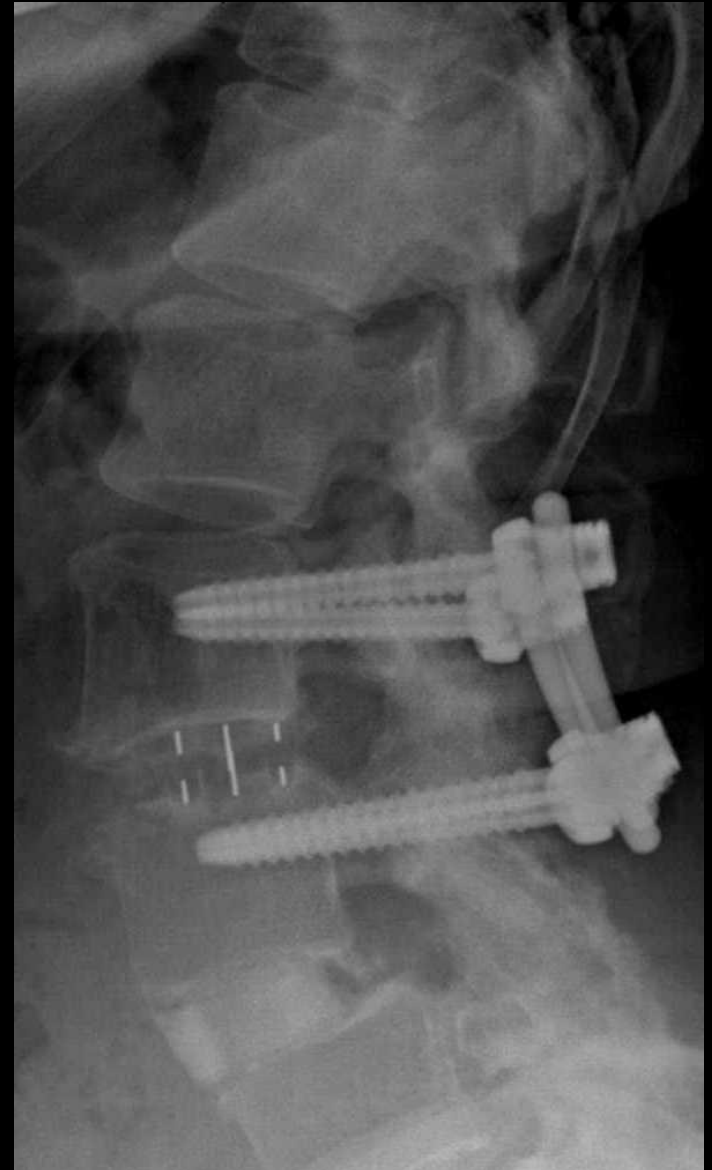
Inter-body graft device

- Central cavity
 - Autologous bone chips
 - Iliac, fibular, femoral grafts
 - Demineralized bone matrix
 - Bone morphogenetic protein to establish bony fusion.
 - INFUSE Bone Graft combines rhBMP-2 with an absorbable collagen sponge carrier
 - Superior to autologous iliac crest bone graft in obtaining interbody fusion



Inter-body graft device

- Non-metallic synthetic spacers contain two radiopaque markers to enable radiographic assessment of the spacer position
 - Posterior mark is at least 2 mm anterior to posterior border of adjacent vertebral body



Inter-body grafts and implants

- Choice of bone graft material may impact the radiographic assessment of interbody fusion.
 - Iliac crest bone graft or another graft substitute material is used to fill the device, the graft is radiopaque, and **graft remodeling or resorption or both must be evaluated to determine if fusion is progressing.**



Inter-body grafts and implants

- Inadequate fixation and subsequent motion may cause the bone graft to resorb rather than to be incorporated. This in turn puts hardware at risk of fracture



13 months later

Inter-body grafts and implants

- Choice of bone graft material may impact the radiographic assessment of interbody fusion.
 - When a graft such as INFUSE Bone Graft is used, the graft is radiolucent at placement and fusion assessment is based in part on an increase in radiodensity that correlates with de novo bone formation
 - New bone formation within or adjacent to the fusion device is typically seen by 3 months after the fusion procedure and usually progresses for 18–24 months
 - Often little change will be evident in a given 3-month period.



Inter-body grafts and implants

- In intact fusions, the outlines of radiolucent cages become increasingly apparent as the adjacent bone graft consolidates over time with no adjacent lucency or sclerosis



Ray's Criteria for Radiographic Assessment of bridging Osseous Fusion

- Criteria have not been externally validated, but they have gained clinical acceptance and are useful for interpreting postoperative radiographs

Criteria for Radiographic Assessment of Bridging Osseous Fusion

1. Less than 3 degrees of intersegmental position change on lateral flexion and extension views.
2. No lucent area around the implant.
3. Minimal loss of disk height.
4. No fracture of the device, graft, or vertebra.
5. No sclerotic changes in the graft or adjacent vertebra.
6. Visible bone formation in or about the graft material.

Source.—Reference 8.

Inter-body grafts and implants

- Washington University (2008)
 - CT scans are normally obtained 3, 6, 12, and 24 months after a fusion procedure or until solid arthrodesis has been obtained.
 - Following is a summary of the typical findings for each assessment period:

Inter-body grafts and implants

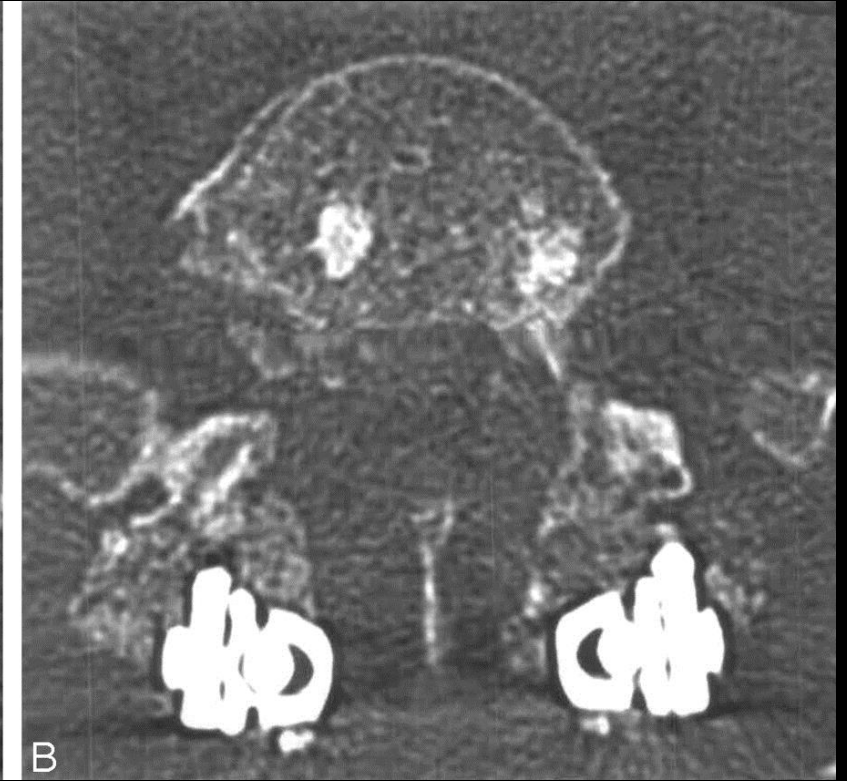
- Three months
 - Early bone healing is occurring
 - Perihardware lucencies that would indicate loss of fixation
 - Subsidence, or sinking of the implant into the vertebral body above or below
 - Direct impact on ligamentotaxis and therefore reflects a partial loss of structural stability

Inter-body grafts and implants

- Six months
 - Bony arthrodesis may be nearing completion with evidence of bridging trabecular bone
 - Bridging bone is usually seen lateral to the implant and may also be noted within the implant itself
 - Initial bone formation tends to occur between the lateral aspect of the fusion device and the annulus
 - No cystic lucencies adjacent to the implant and no linear defects through the bridging bone
 - Presence of these findings is indicative of delayed union

Inter-body grafts and implants

- Twelve months
 - Findings at 12 months are similar to those with the 6-month CT scan
 - Trabecularization should be more mature with obvious bridging bone between vertebral bodies
- Twenty Four Months
 - Performed only if solid arthrodesis is not present at 12 months
 - Disk space has begun to consolidate more completely with filling of trabecular bone around the implants
 - Any evidence of lucency or cystic changes at the device margins or lucent lines through the fusion mass is an indicator of nonunion, or failed fusion



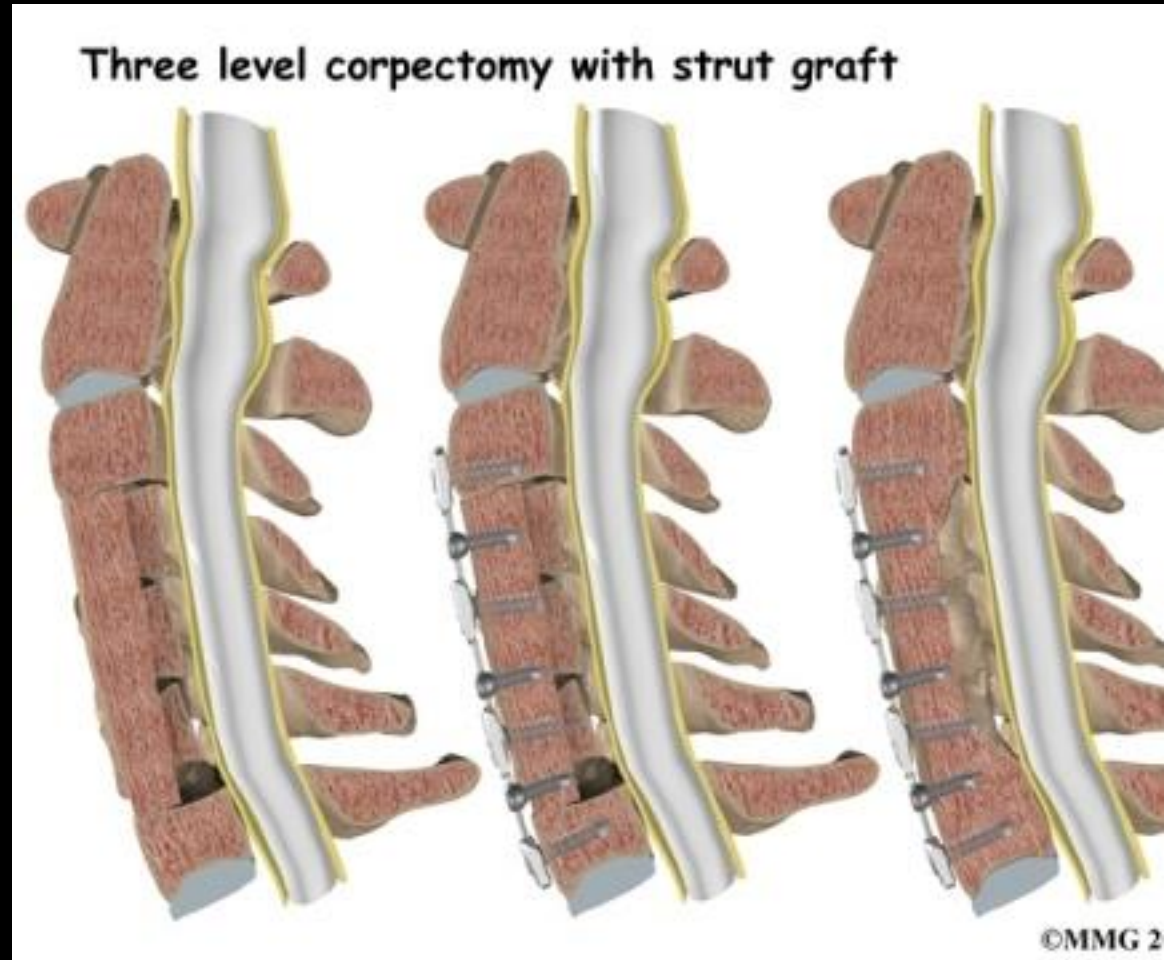
Vertebral Body Replacement (corpectomy)

- Spinal diseases of neoplastic, infective or traumatic processes may necessitate resection of one or more vertebral bodies under certain circumstances
- Maintaining the lost spinal segment height is mandatory to preserve functionality and avoid further neural related complications



Vertebral Body Replacement (corpectomy)

- Large strut grafts
 - Femoral strut allografts are designed for use in the lumbar or thoracic spine
 - Fibular strut allografts or tricortical iliac crest grafts may be used in anterior cervical corpectomy



DYNAMIC SPINE STABILIZERS

Spinal dynamic stabilization

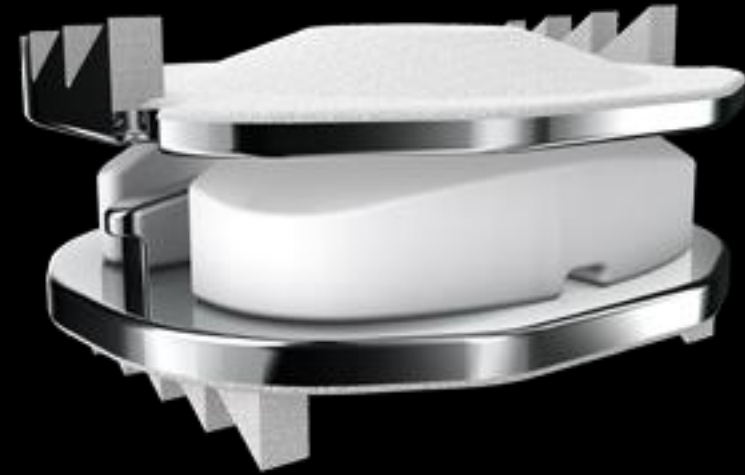
- Concept of dynamic stabilization relies upon altering load bearing and controlling abnormal motion
- Alternative to fusion in some patients with low back pain
- Limits the stress placed on the segment adjacent to the level of fusion and thus helps prevent progressive degeneration

Spinal dynamic stabilization

- Wide variety of dynamic stabilization devices are available
 - Total disc replacement
 - Pedicle screws and artificial ligaments
 - Interspinous process decompression devices
 - Posterior element replacement systems

Total disk replacement

- Pain is believed to be discogenic in origin with no nerve root involvement as well as absent spinal stenosis or spondylolisthesis
- At least 4 mm of residual disk height and a lack of significant endplate degeneration to provide satisfactory anchorage for the replacement device are pre-requisites



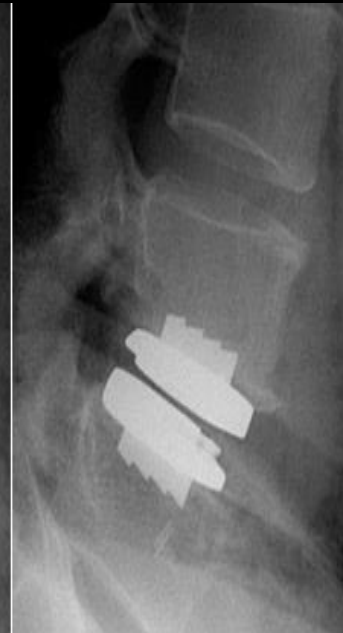
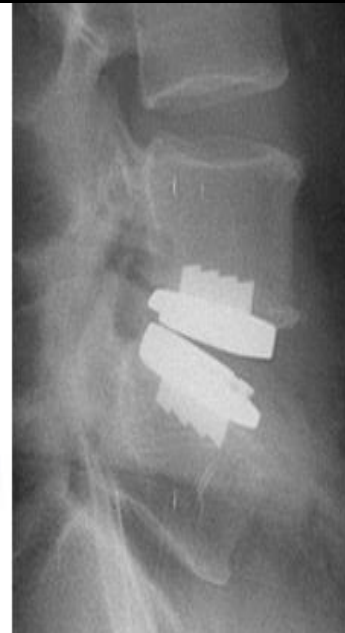
spinegroupbeverlyhills.com

Total disk replacement

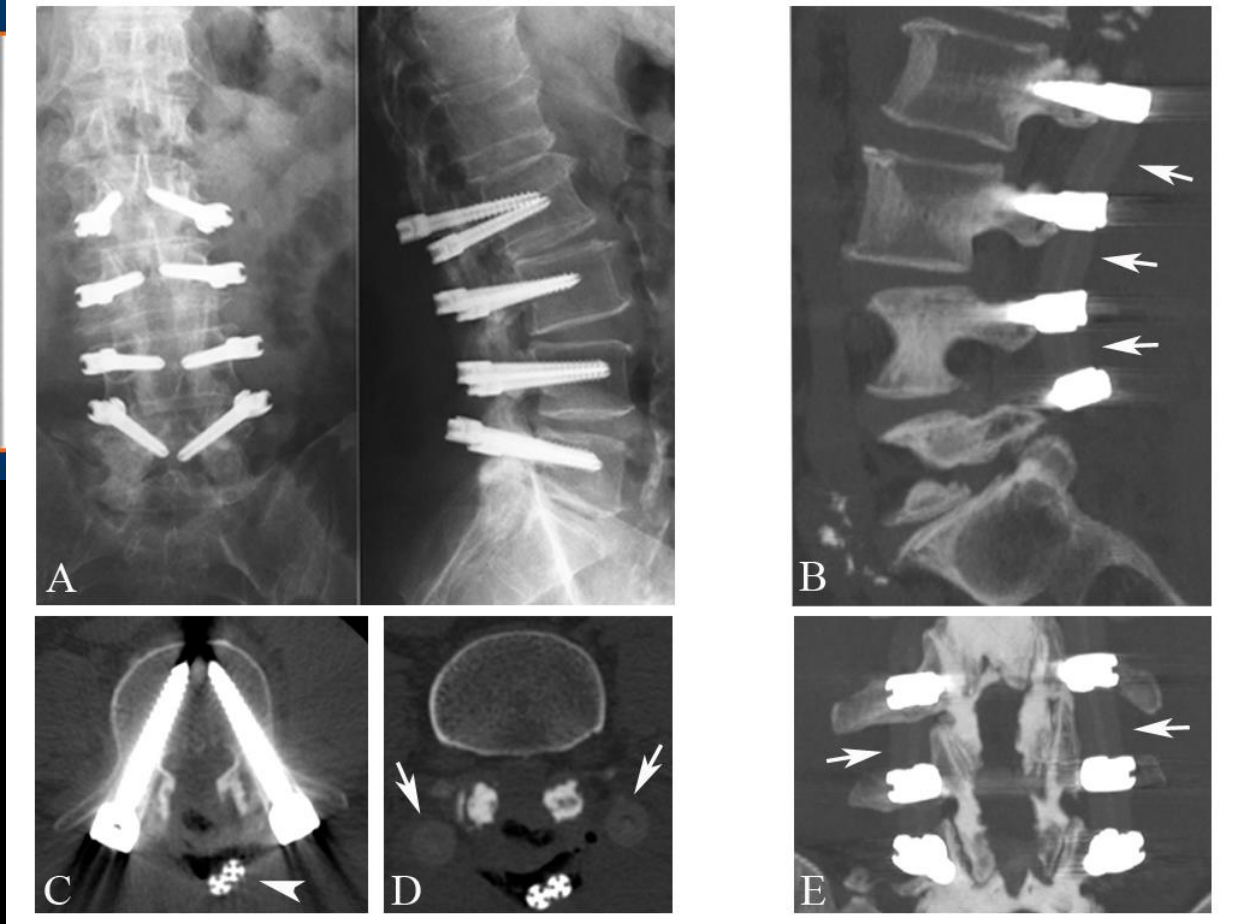
- Materials used by different manufacturers vary considerably, with many different combinations of metals and polymers.
- Long-term evaluation is still ongoing in the literature
 - Yang et al, showed good clinical outcome, restored cervical spine mobility and prevented accelerated adjacent cervical segments degeneration at 24-mo follow-up
 - Yajun et al, reported equivocal results for the treatment of lumbar degenerative disc disease compared with fusion after a 2-5-year follow-up period

Total disk replacement

- Design characteristics of these devices are variable
- Positioning
 - Located midline between the two pedicles on AP radiographs or axial or coronal CT scans
 - Center of rotation should be located in the posterior half of the disk space yet it should not extend beyond the posterior vertebral body line

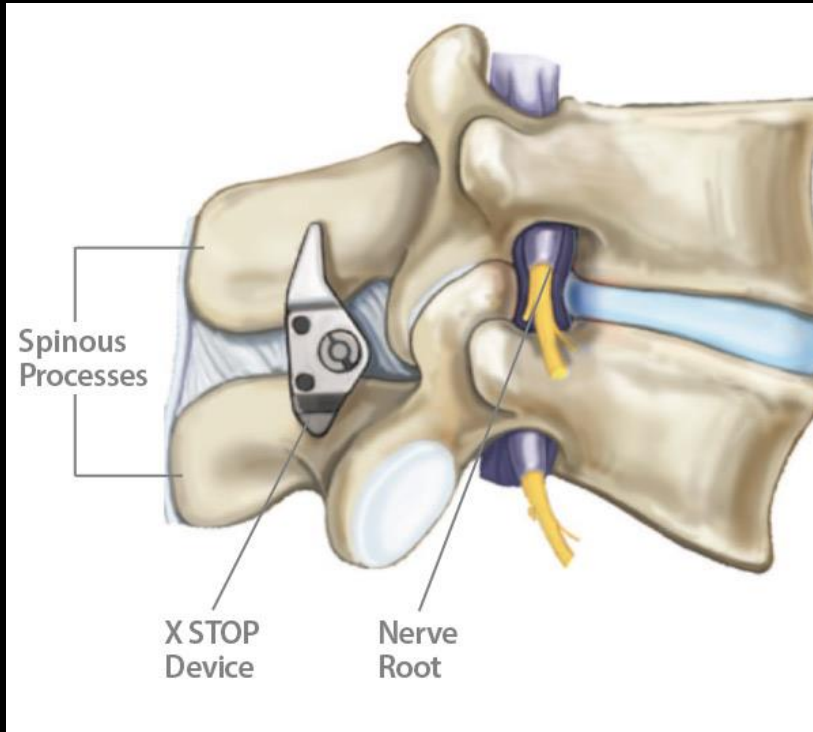


Pedicle screws and artificial ligaments



http://posterng.netkey.at/esr/viewing/index.php?module=viewimage&task=&mediafile_id=410863&201201310039.gif

Interspinous process decompression devices



www.augustahealth.com

<http://www.coflexsolution.com/content/your-back-and-leg-pain-lumbar-spinal-stenosis>

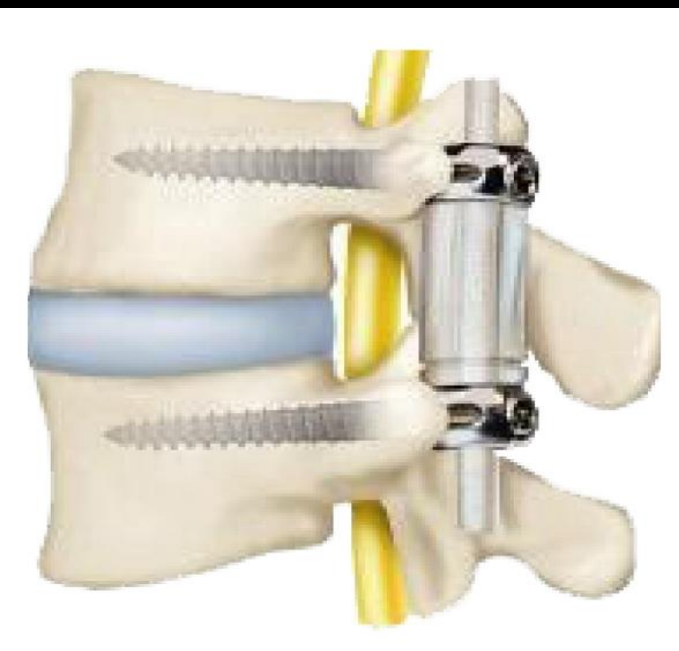
Spinal dynamic stabilization



At rest: The Dynesys System supports an intervertebral joint between L4 and L5.

Flexion: Pedicle screws hold the polyethylene cord secure, supporting the affected joint as the spine bends forward.

Extension: The external spacer -- a polyurethane tube -- provides support for the affected joint as the spine bends backwards.



Hardware Placement Complications

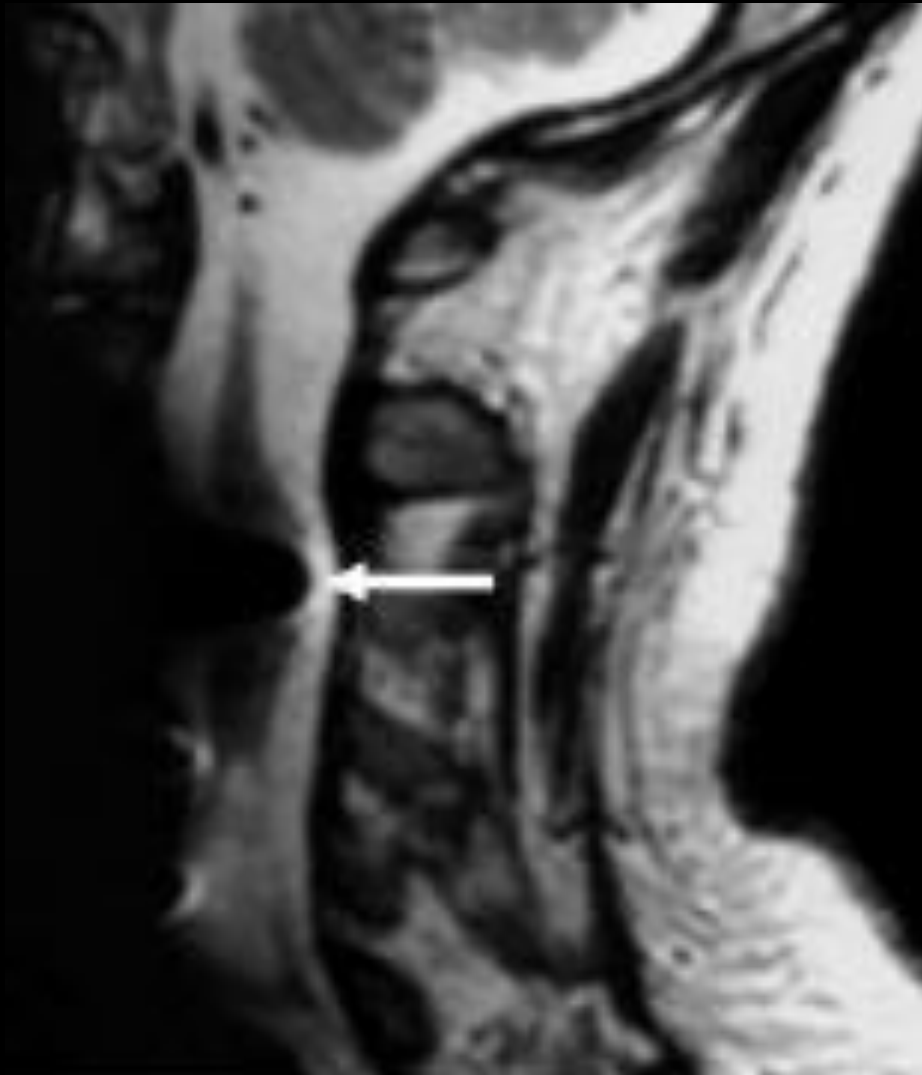
Screw malplacement complications

- Anterior cervical spine
 - Transient nerve palsies
 - Arterial (vertebral and carotid arteries) dissections
 - Esophageal tears
- Anterior procedures in the thoraco-lumbar spine
 - Vascular injuries are also more common
 - Thoracic duct injury
 - Injury to the long thoracic or phrenic nerves

Anterior screws

- Anterior plates are anchored to the underlying vertebral bodies with screws
 - Screws should enter the anterior cortex of each vertebral body and be seated in the posterior bone without impingement on the cord for firm purchase of the screws and to promote posterior graft material compression and enhance bony fusion
- Should not enter an adjacent end plate and should be at least 2 mm from the superior and inferior end plates
 - Inadvertent mal-positioning of cervical screws within adjacent disc material predisposes for aseptic loosening of the hardware and a high risk of vertebral body fracture as the disc material can not hold the screws

Anterior screws

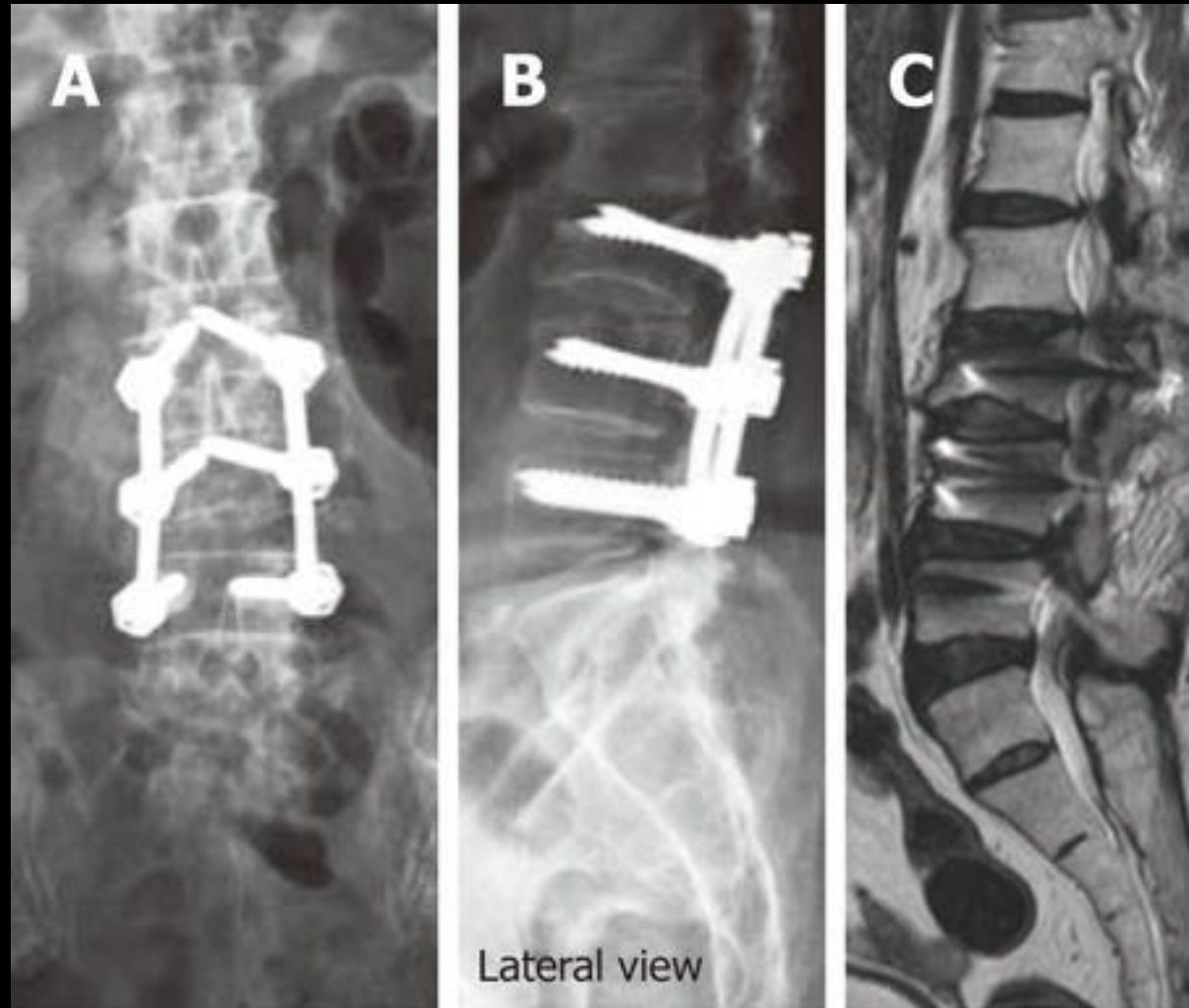


Pedicular screws

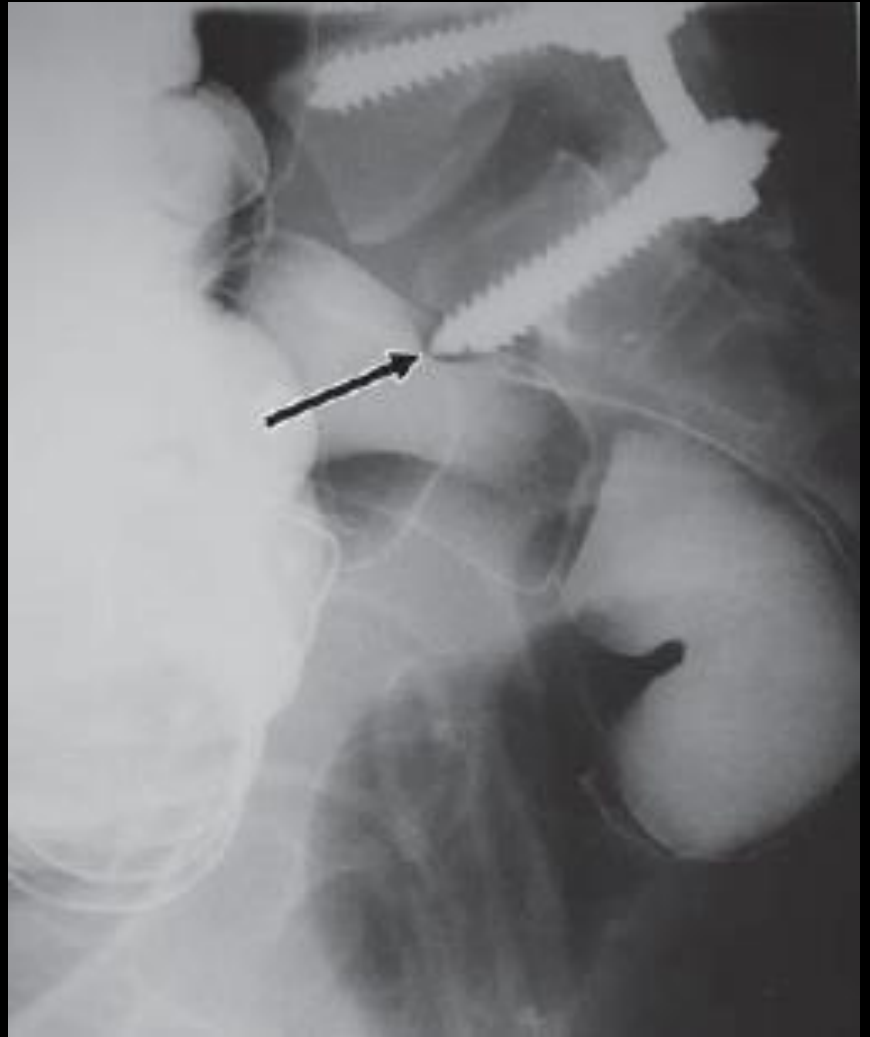
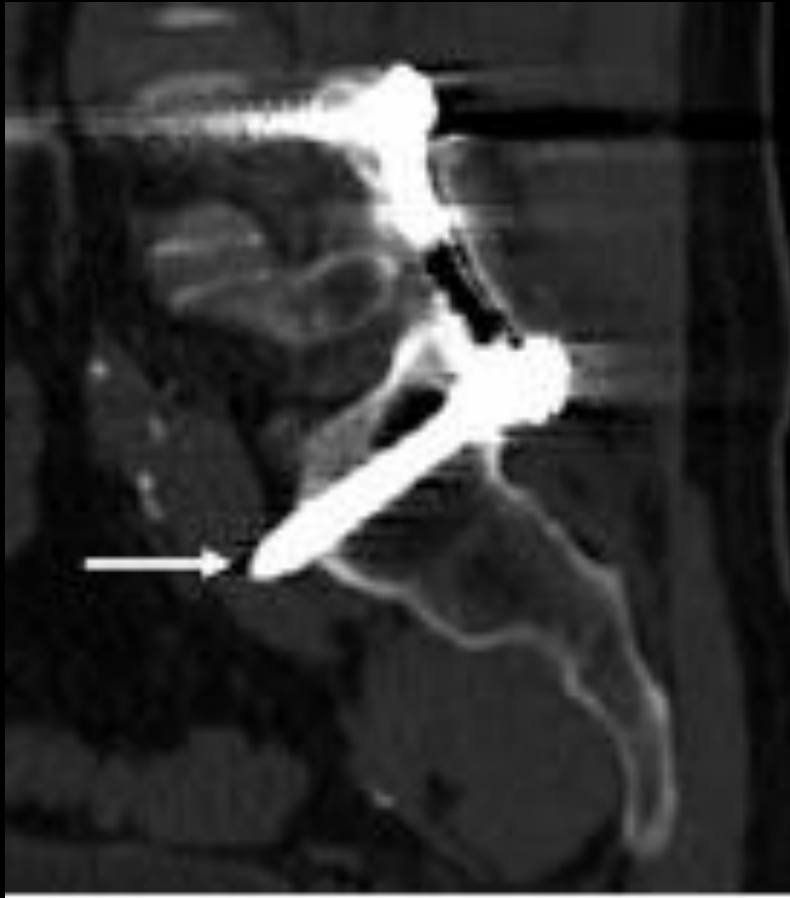
- Combinations of plates and/or rods with pedicle screws are interconnected for spinal instrumentation, till bony fusion ensues
- Placement
 - Medial aspect of the pedicle and contained within the pedicle
 - No consensus on their optimal length (> 50% of its length within the vertebral body)
 - Should not break through the integrity of adjacent cortices or end-plates
 - Sacral screws may be anchored in the anterior cortex of the sacrum for additional stability

Pedicular screws

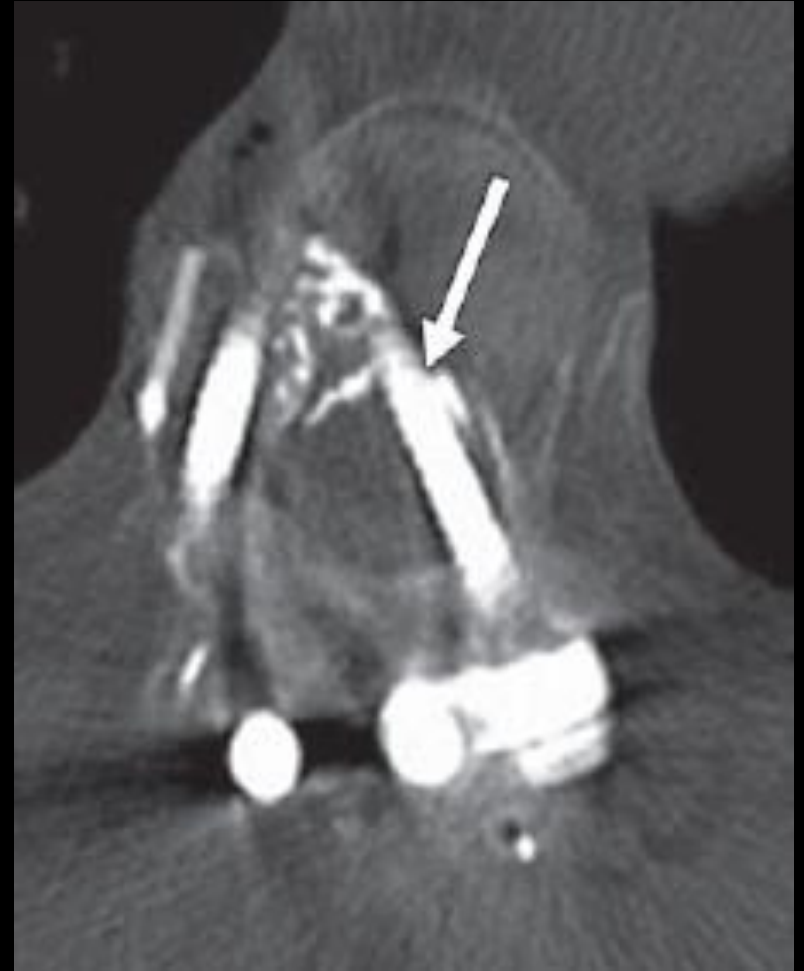
- Placement
 - Should not break through the integrity of adjacent cortices or end-plates



Posterior screws



Screw placement



Hardware Failure

Only in cases where there has been breakage of the hardware and there is obvious failure of the spinal construct would back surgery be considered less than one year postoperatively

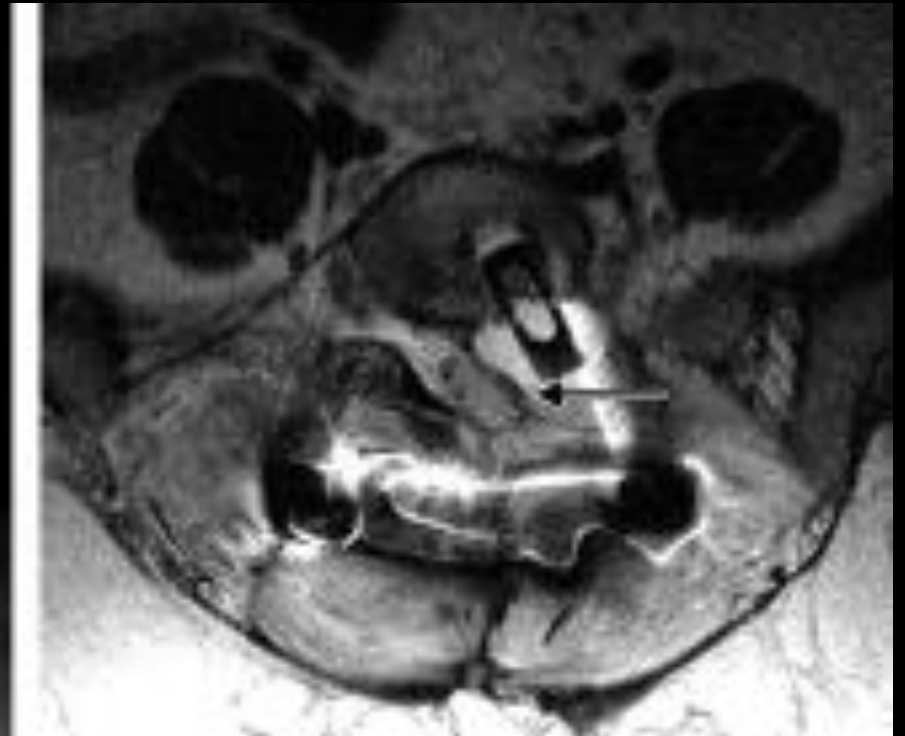
Spinal hardware-related complications

- Metal failure especially early in the postoperative course after back surgery, is an indicator of continued gross spinal instability
- Larger a patient is and the more segments that are fused, the higher the likelihood of implant failure

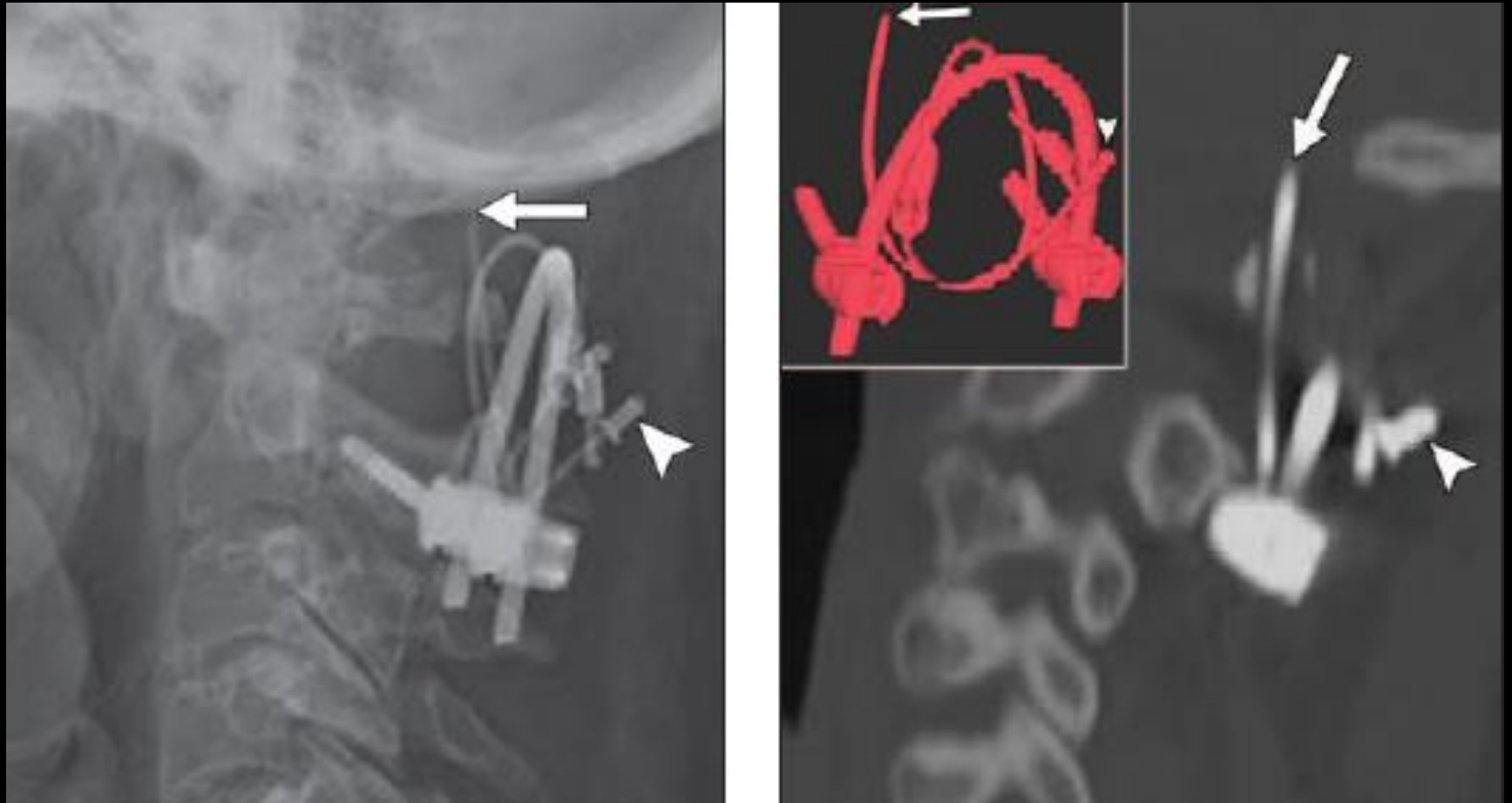
Spinal hardware-related complications

- Hardware failure
 - Implant breaks
 - Most commonly as a result of metal fatigue from the repeated stress in spinal movements
 - Device becomes largely dissociated from the underlying bone
 - Rod migration or dislodgement
 - Rod breakage
 - Hook cutout or disengagement
 - Wire breakage
 - Screw cutout and failure
 - Can cause chronic tissue irritation leading to pain, bursa formation and even pressure sores with tissue necrosis

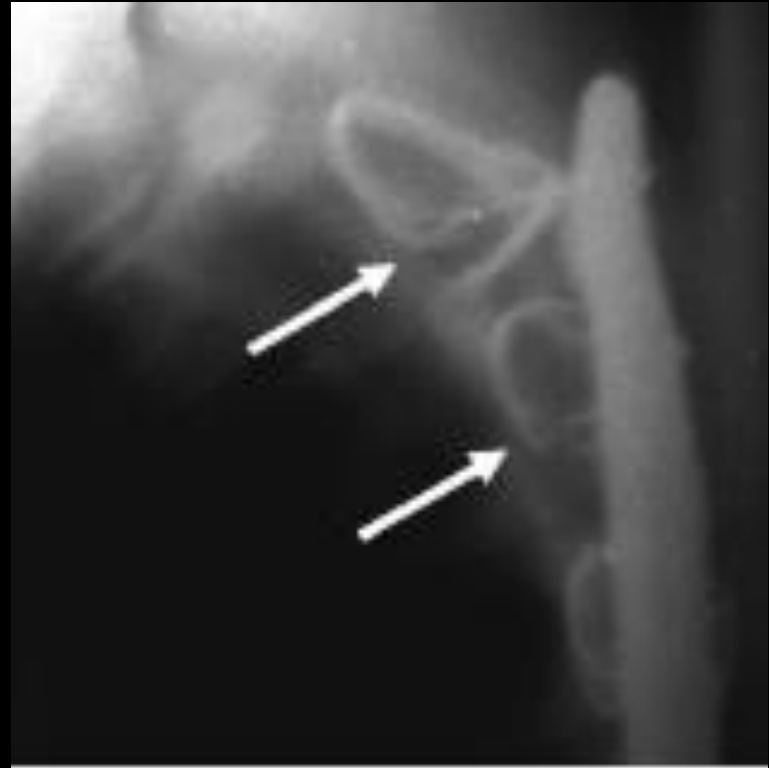
Bone graft herniation



Wire break



Wire break

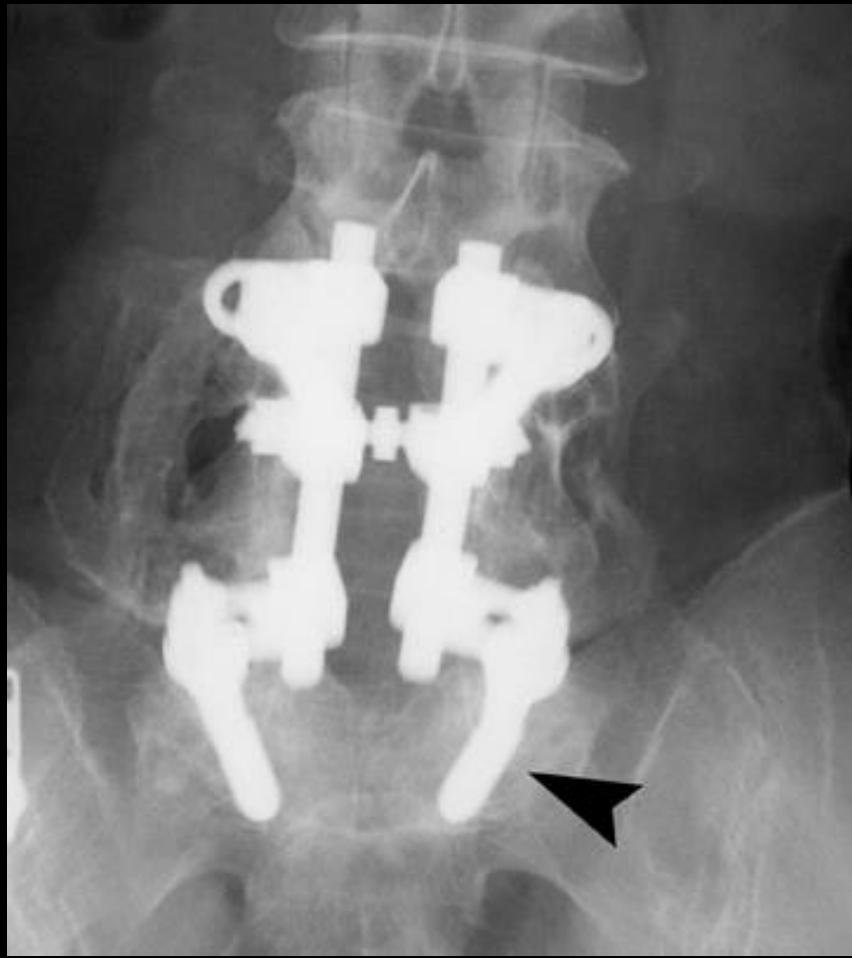


Screw complications

- Screw complications
 - Lonstein et al (retrospective review of clinical outcomes with placement of 4790 pedicle screws)
 - Screw fractures in 0.5%
 - Penetration of the anterior cortex in 2.8%
 - Pedicle fractures in 0.6%-2.7%
 - Dural tears in 1%
 - Nerve root irritation in 1% (medial angulation of the screw with resultant violation of the medial cortex of the pedicle)

Screw fracture

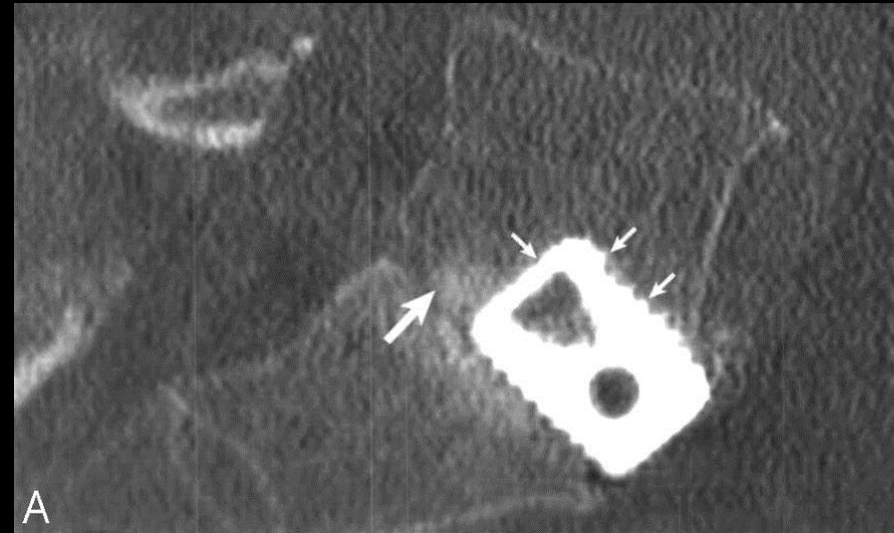


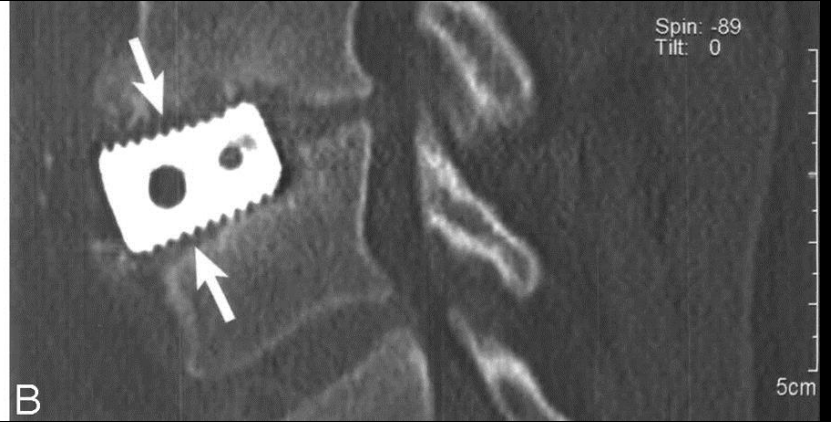
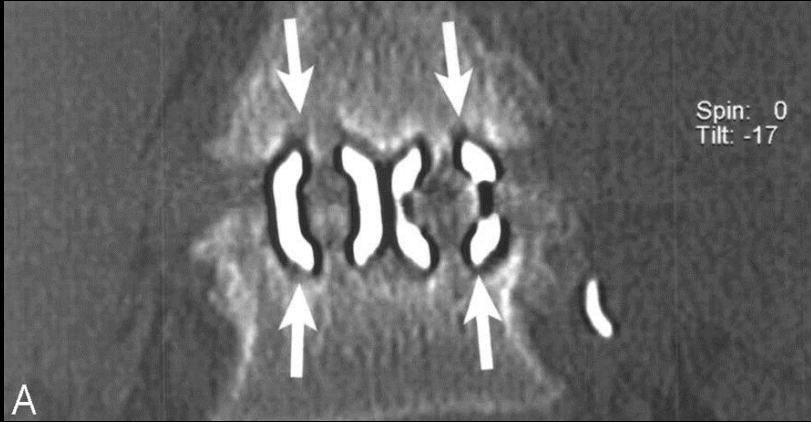




Spinal hardware-related complications

- Subsidence
 - Fusion device sinking into one or both of the adjacent vertebral bodies
 - Increased incidence of failed fusion because the loss of mechanical structural support allowing the fusion device or bone graft material to shift or dislodge



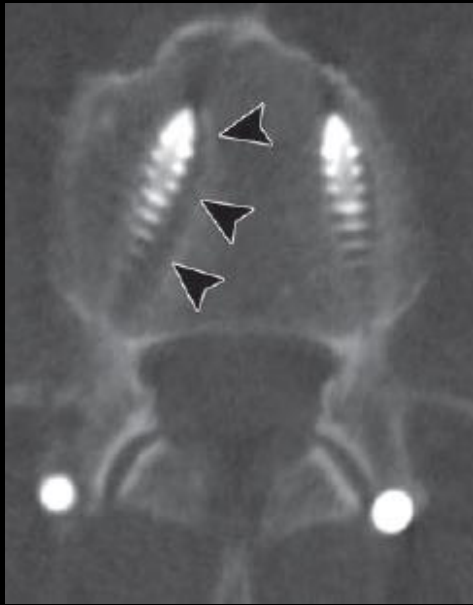


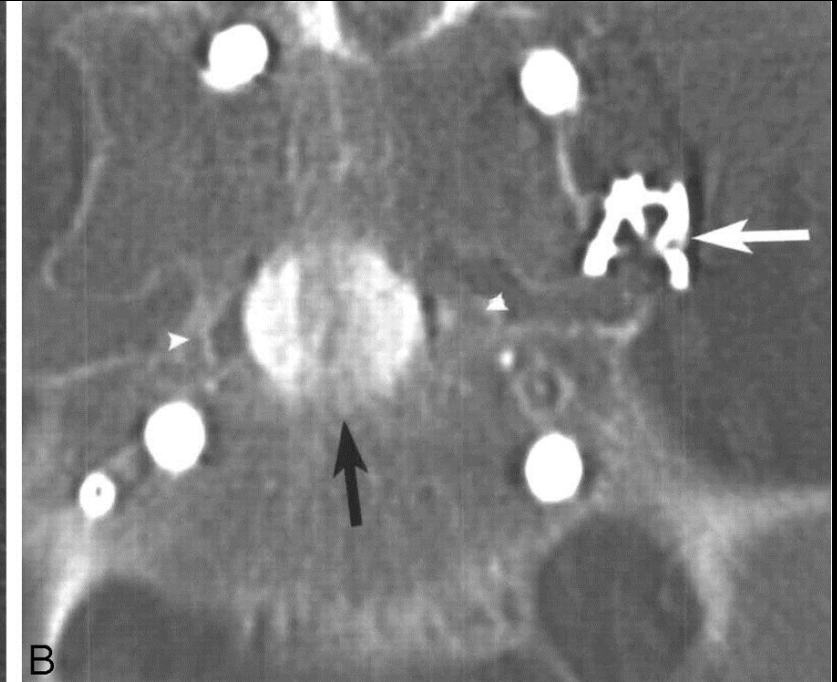
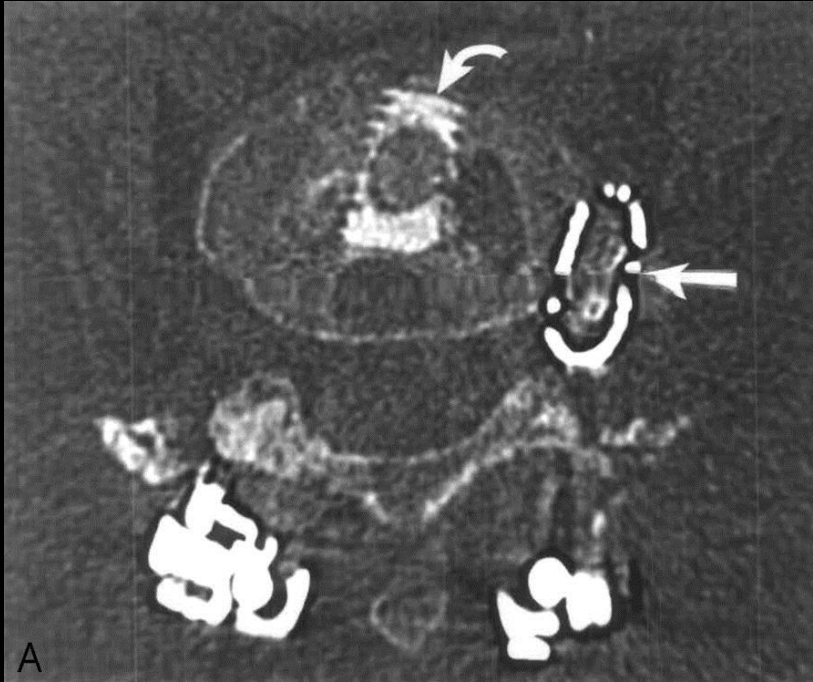
Spinal hardware-related complications

- Aseptic loosening
 - Loosening of pedicle screws
 - Rim of lucency around the screw threads (or any hardware) especially when the lucency exceeds 2 mm or increases in size
 - Loose screws will often gradually retract and may eventually be expelled from the bone entirely with eventual hardware failure
 - Particulate debris, produced by component wear, attracts and activates tissue phagocytes and with repeated but unsuccessful attempts of phagocytosis to non-digestible metal particles damages adjacent bone and cartilage by enzymatic release
 - Associated with delayed or failed fusion
 - Cause the bones to weaken and predisposes them to fracture and it leads to hardware failure

Screw dislodged







PSEUDOARTHROSIS

Posterolateral gutter fusion

- Posterior fusion is characterized by autografts placed along decorticated facets and/or laminae
- Early postoperative radiographic appearances are quite variable
 - Large solid fusion masses
 - Small wispy bone grafts hardly show up on plain X-ray and/or on CT, particularly if small amounts of graft were placed along the posterior elements and/or transverse processes
- Gradually consolidates over several months into a solid bony fusion within 9-12 mo postoperatively, if successful fusions have ensued

Pseudoarthrosis

- Subtle or low-grade instability at the fusion site results in pseudoarthrosis or fibrous union.
- Pseudoarthrosis is defined as failure of attempted spinal fusion to achieve solid bony arthrodesis by **1 year after surgery**.
- Increased risk factors
 - Smoking
 - Long-term use of non-steroidal anti-inflammatory drugs
 - Underlying conditions such as scoliosis
 - Osteoporosis
- May be a source of **pain generation**

Pseudoarthrosis

- CT/Radiographs
 - Mature pseudoarthrosis appears as a clearly linear lucency across the graft material with sclerosis on its margin on radiographic films
- MRI
 - With newer titanium and cobalt-chromium implants MRI can depict focal high signal intensity in the region of pseudo-articulation on T2-weighted images and bands of low intensity on T1-weighted images
 - Reactive marrow changes and enhancement with gadolinium due to abnormal motion may also be seen
- Nuclear Medicine
 - Increased radiotracer uptake is expected at sites of motion 6-9 mo after operation
- Interventional
 - US or CT-guided anesthetic injections are recommended by some groups to prove or disprove pseudoarthrosis as the source of pain.

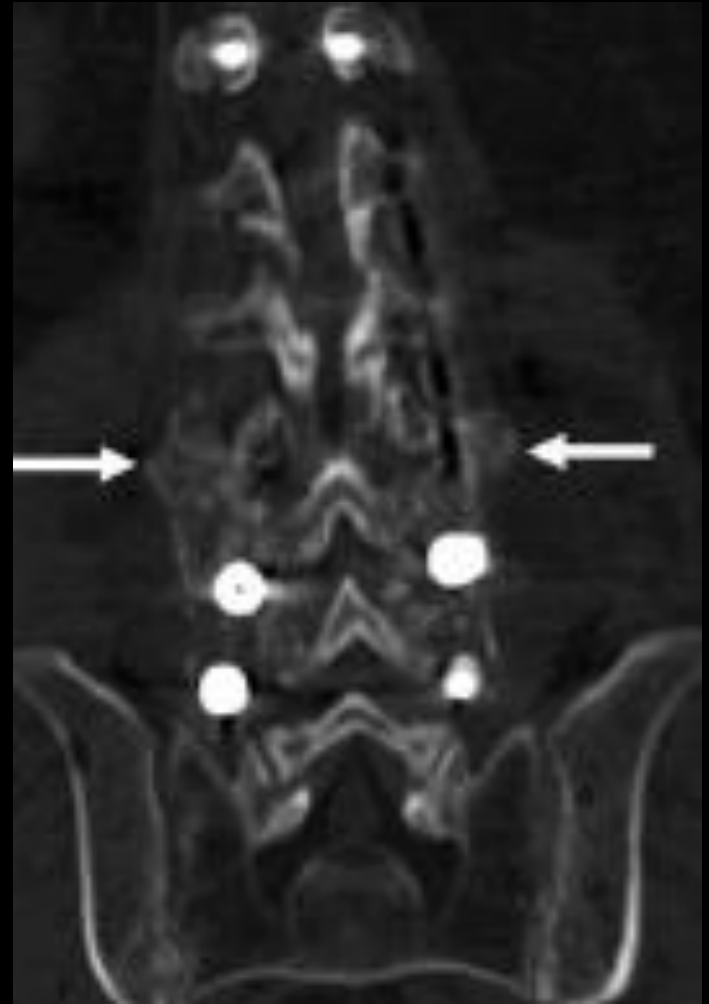
Nuclear medicine

- Bone scintigraphy including single-photon emission CT (SPECT)
 - More sensitive and less specific than plain radiographs and cross-sectional imaging
 - Fusion sites
 - Should be “cold” after 9-12 mo
 - Very focal intense activity may reflect the presence of non-union (pseudoarthrosis), as opposed to more ill-defined or diffuse activity that reflects normally increased bone turnover in a fused spine
 - Help in infection detection in the region of metal implants
 - Technetium and labeled white blood cell studies
 - Accuracy of this dual radiotracer technique exceeds 90%

Interventional

- US or CT-guided anesthetic injections
 - Determine the source of pain around a prosthesis, e.g., a hook site, facet joint, or disc or in a suspected pseudoarthrosis region
 - Relief of pain after anesthetic injection confirms the source of pain and allows for proper selection of treatment options
 - Aspiration of osseous, disc, or soft tissue lesions is also useful when infection is suspected

Pseudoarthrosis



Pseudoarthrosis

43 y/o male



POSTSURGICAL COMPLICATIONS - NONHARDWARE

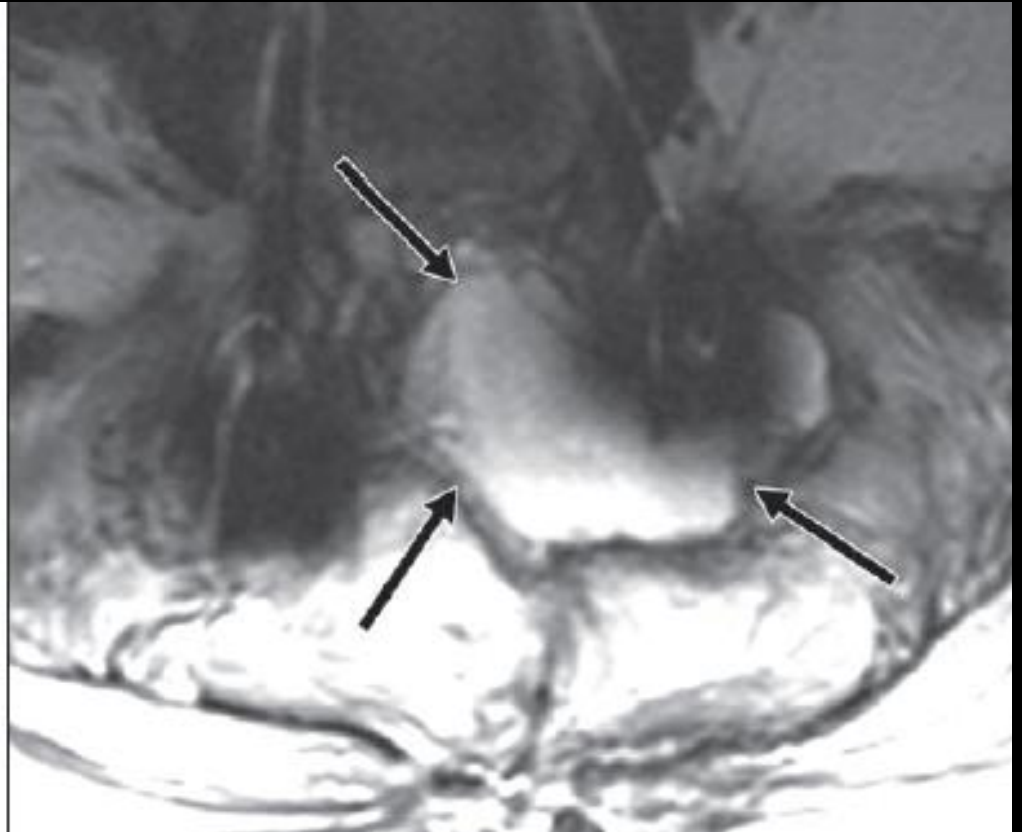
Postoperative Complications

- Spinal fixation and fusion are long surgical procedures with prolonged immobilization or recumbency
 - Brachial plexus injuries
 - Superior mesenteric artery syndrome
 - Thrombophlebitis
- Medical complications
 - Genitourinary infections occur in 20%
 - Deep venous thrombosis in 25% of patients
 - More common in patients who have post-traumatic paralysis or prolonged hospitalization
 - Gastrointestinal hemorrhage may be as high as 40% in patients receiving steroid therapy

Postoperative complications

- Acute onset of neurologic symptoms in the immediate postoperative setting
 - Hematoma, a surgical emergency that requires urgent surgical decompression

Hematoma



Infections

- Postoperative infections
 - May occur in the immediate post-operative period or present latently several months after surgery
 - Infection may involve any tissue in the postoperative bed
 - Direct Implantation
 - Hematogenous spread and/or wound contamination
 - Staphylococcus epidermidis and Propionibacterium acnes are the main organisms associated with implant infections

Infections

- Infections
 - Patients often present with pain, hotness, skin redness and swelling at the operative site with sinus formation draining deep collections in some cases
 - Superficial soft-tissue infections are easy to diagnose clinically
 - MRI may depict fluid collections, abscess formation and intense enhancement following the administration of IV gadolinium-based agents

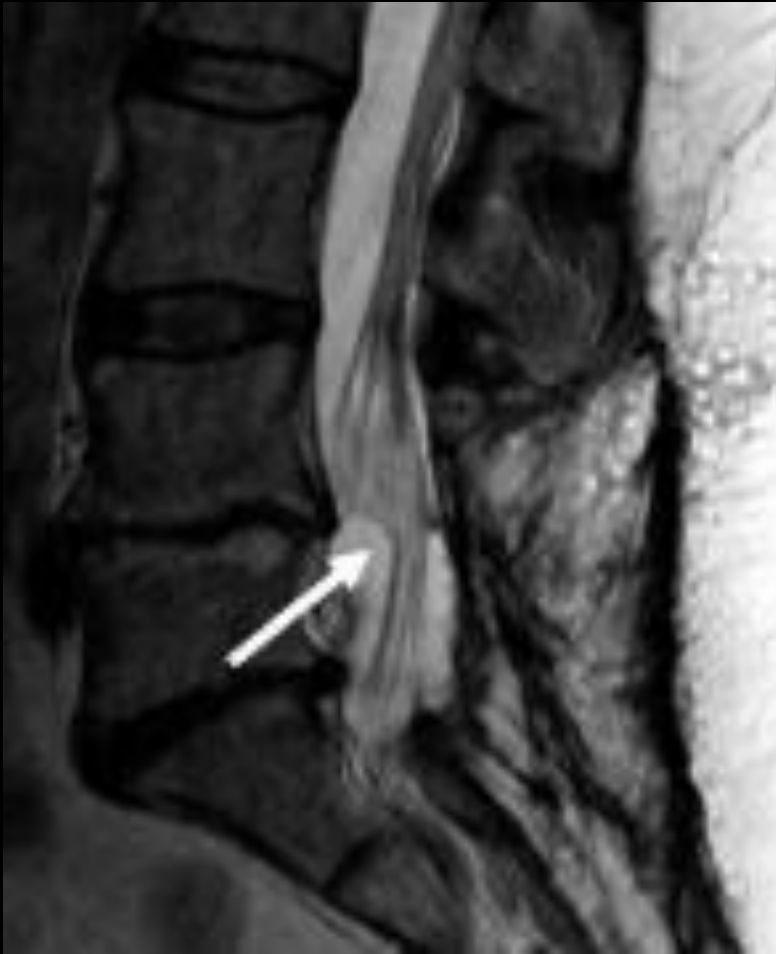
Infections

- Postoperative infection can occur in the form of
 - Meningitis
 - Arachnoiditis
 - Superficial or deep wound infection
 - Abscess formation
 - Osteomyelitis
 - Diskitis
 - Radiographs of patients with diskitis classically show a collapse of the disk space, destruction of the adjacent endplates, and evidence of osteomyelitis in the adjacent vertebral bodies
 - MR imaging may be useful for confirming the diagnosis.
 - Disk biopsy also may be performed
 - High sensitivity for the detection of bacterial pathogens
 - Lower detection rate for fungal infections

Arachnoiditis



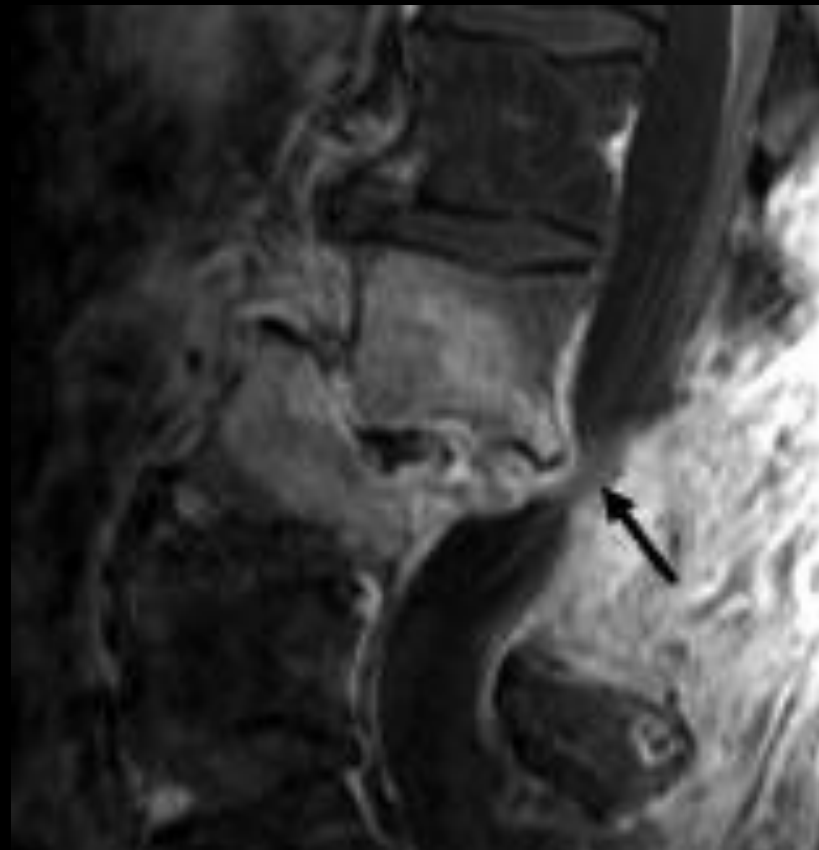
Arachnoiditis



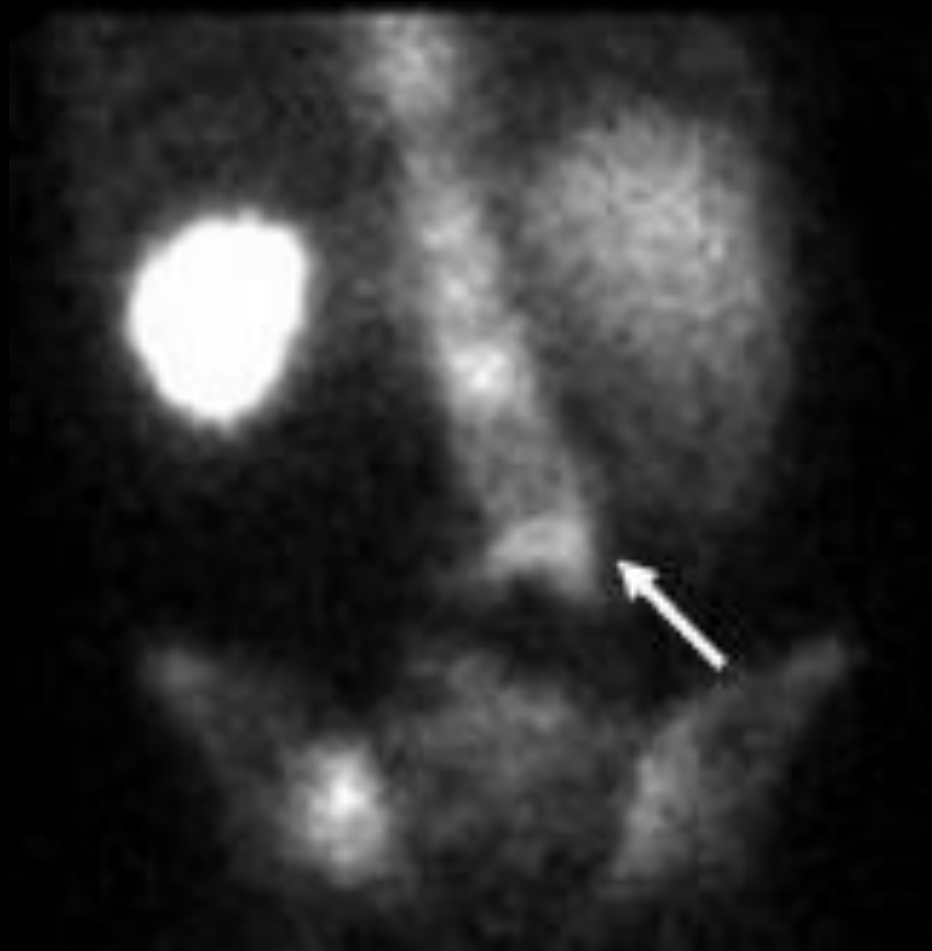
Discitis



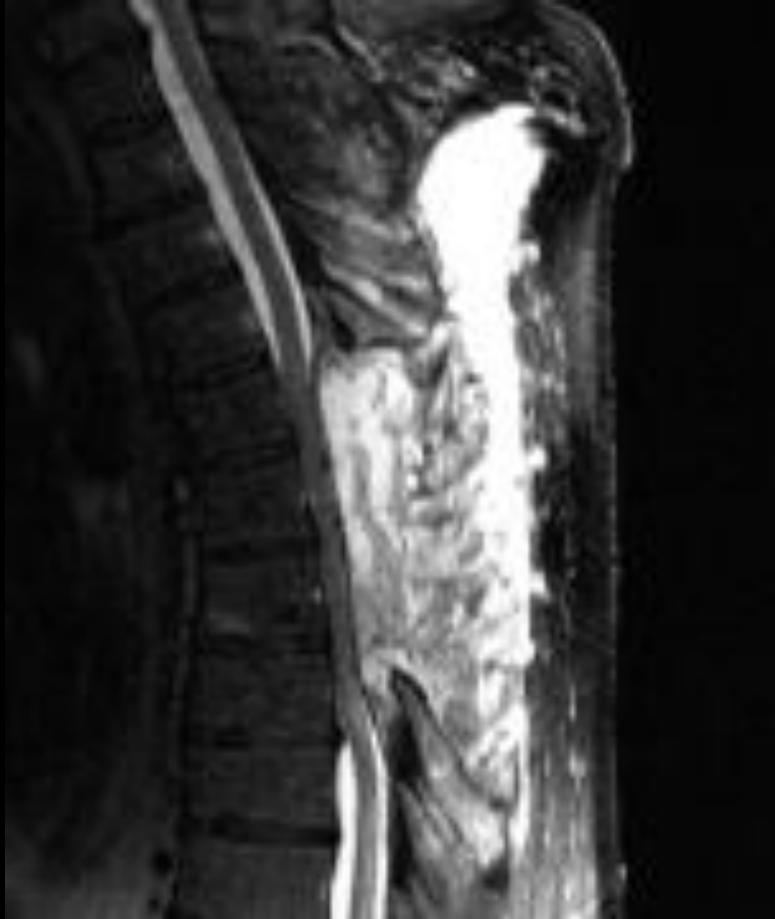
Post operative & 6 months later



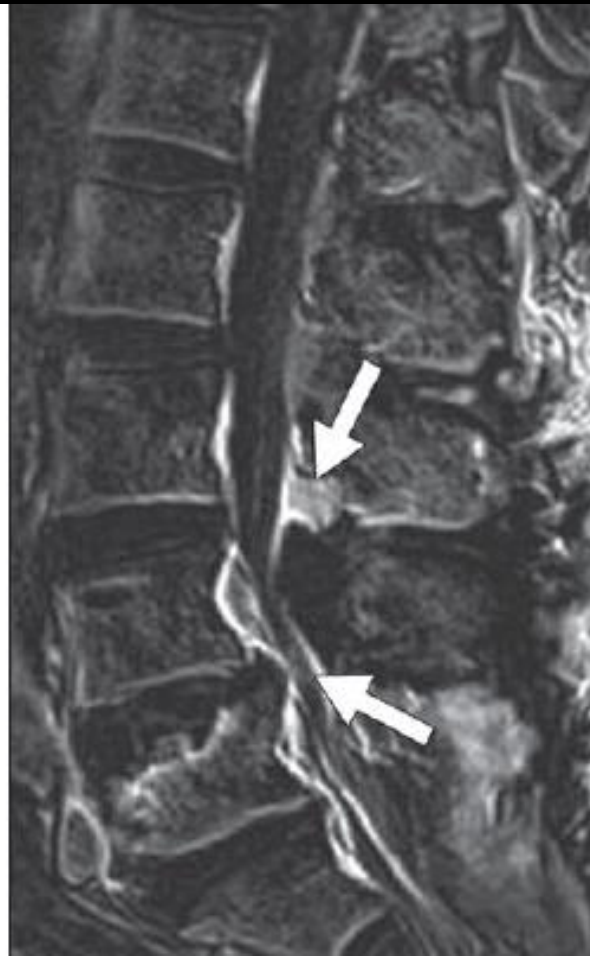
Discitis



Abscess



Abscess



Recurrent Symptoms

- Although surgery at the wrong level is an uncommon occurrence, it may account for the persistence of clinical symptoms.



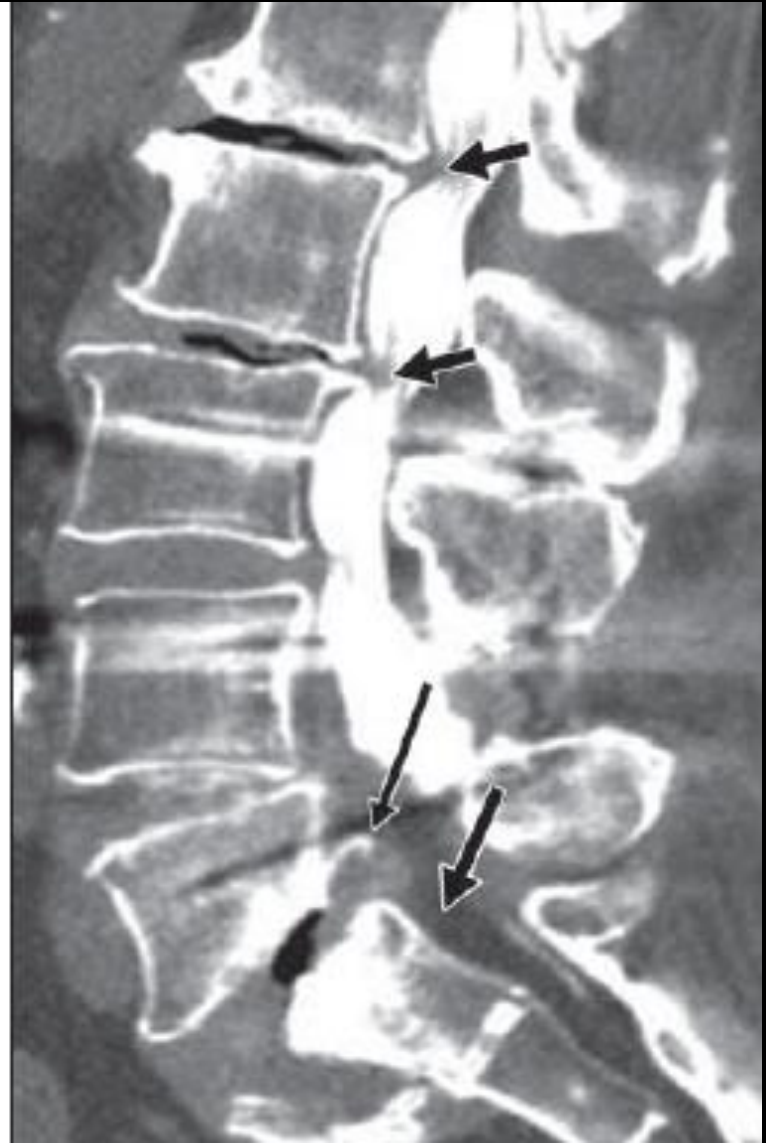
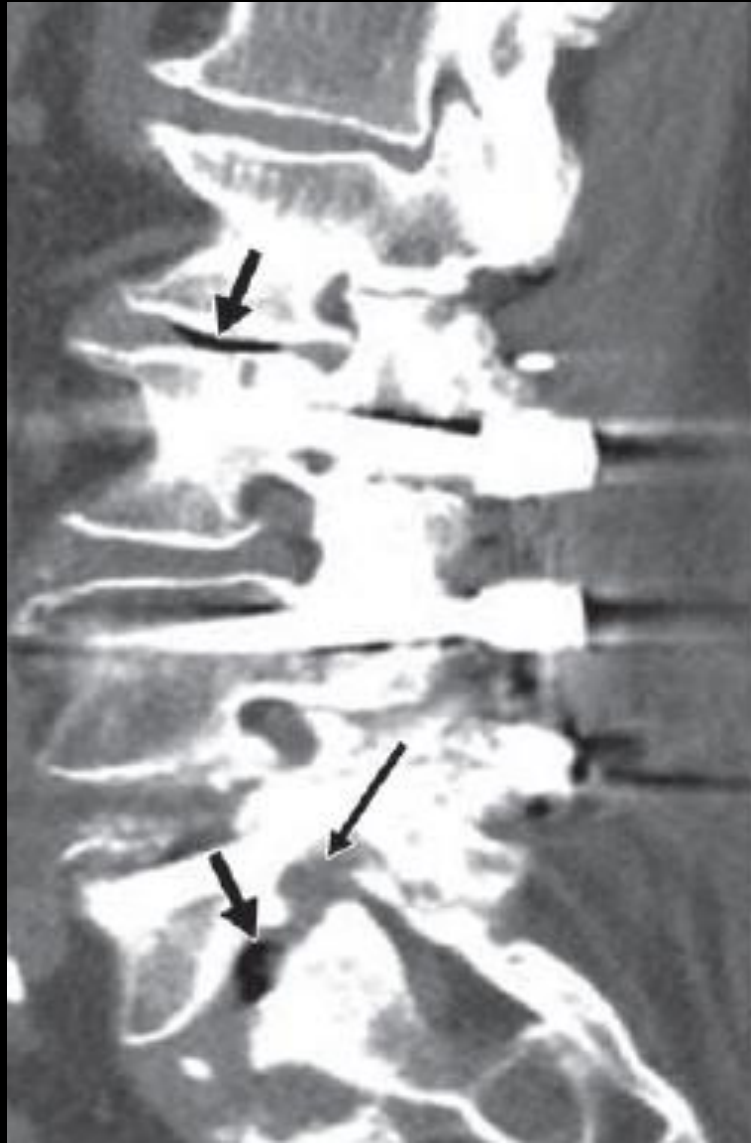
Recurrent Symptoms

- Noncompliant with postoperative spinal precautions (avoiding heavy lifting, excessive bending or twisting of the trunk, or exposure to high impact activities)
- Trauma is a common cause of immediate hardware failure

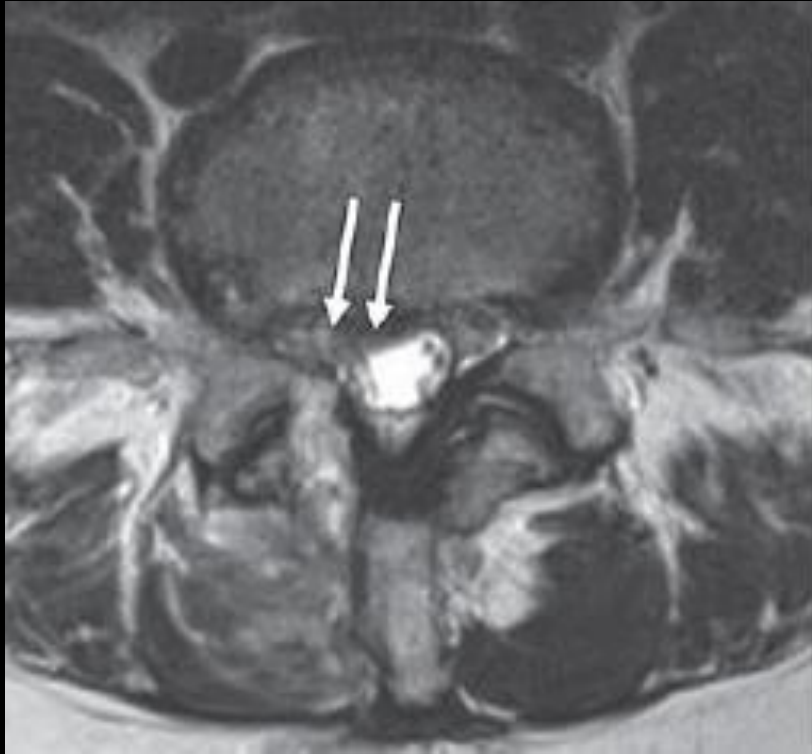
Recurrent Symptoms

- Recurrent pain, new pain, and neurologic dysfunction after a period of initial relief
 - Disk herniation
 - Nonenhancing mass pushing the nerve root posteriorly indicates recurrent disk herniation
 - Epidural scar formation
 - Presence of an enhancing mass displacing the nerve root anteriorly indicates epidural fibrosis
 - Adjacent segment disease
 - Late hardware complications
 - Failure of fusion surgery also places stress on the instrument itself owing to continuous motion and pseudoarthrosis, causing hardware fracture

Disc herniation



Epidural Fibrosis



Recurrent Symptoms

- Junctional failure/Adjacent segment disease
 - Successful spinal fusion permanently alters the mechanics of vertebral segments at adjacent levels resulting in accelerated degenerative changes in the vertebrae, ligaments, and intervertebral disks
 - Larger a patient and the more segments that are fused, the higher the likelihood
 - Commonly seen in the lumbar region compared with other regions
 - Much less likely to happen if only the L5-S1 level is fused, as this segment typically does not have much motion and fusing this level does not change the mechanics in the spine all that much.
 - Most of the motion in the spine is at the L4-L5 level, and to a lesser extent at L3-L4. When the L4-L5 level is included in the spine fusion it transfers a lot of stress to L3-L4.
 - Complication is reported in 10.2% of patients with posterior fusion and instrumentation

Junctional failure

2.5 years later



Patient related causes of hardware failure

- Medical causes of hardware failure
 - Weakened bone
 - Metabolic bone disease
 - Severe osteopenia may not be appropriate candidates
 - Morbid obesity adds to the technical difficulty of spine surgery and exerts greater stresses on instrumentation
 - Smoking increases the rate of pseudo-arthritis development after fusion

ALOD

- Adjacent level ossification development (ALOD) was described as a long-term sequela to anterior cervical plating
 - Park et al
 - Likelihood of ALOD with anterior cervical plate margin placement within 5 mm of the adjacent disk space
 - Any adjacent-level ossification within the first 12 mo postoperatively resulted in the likelihood of progression to advanced ossification by 24 mo in a later study

ALOD



IMAGING MODALITIES

Radiography

- Baseline radiographs or CR images are essential for evaluating spinal construct position
 - Serve as a starting point for evaluation of future studies, should patients develop symptoms suggesting potential complications
 - Change in position or instrument failure is often easily appreciated on serial radiographs

Computed tomography

- Modality of choice for imaging bony detail in the spine
 - Accurate assessment of component position, particularly for positioning of pedicle screws
 - Evaluating both spinal and construct alignment, and degree of osseous fusion
 - Evaluate the spinal canal
 - Potential post-operative complications

Computed tomography

- Metal-induced artifacts on CT
 - Hardware-related factors such as hardware composition, geometry (shape)
 - Lower X-ray beam attenuation coefficients (density) materials results in fewer artifacts e.g., titanium alloys produce fewer artifacts than stainless steel alloys

Computed tomography

- Location and imaging technical factors
 - Tube current (in milli-ampere-seconds, mAs)
 - Increase in tube current setting using the tube's larger focal spot increases the ability of the X-ray beam to penetrate metal
 - X-ray kilovolt peak (KVp)
 - X-ray tubes operate at 120 kilovolt peak (KVp) as a default setting
 - Higher KVp, e.g., 140 KVp can increase the ability of the X-ray beam to penetrate metal

Computed tomography

- Pitch
 - Pitch equals table translation (in millimeters) per gantry rotation divided by beam collimation
 - As the number of detector rows increases the pitch decreases and this reduces metal artifacts
- Image reconstruction algorithm
 - Wide window settings (3000-4000 HU window width, 800 window levels) facilitates visualization of structures adjacent to metal hardware and reduces the effects of metal artifacts

Conclusion

- Instrumentation used in fusion surgery is not designed to replace the bony elements of the spine, but to stabilize them as the fusion mass consolidates and takes over as the primary source of support.
- Any factor that retards fusion will subject the implant to abnormally high loads for longer periods and ultimately fail when it exceeds its loading capabilities
- Successful fusion permanently alters the mechanics of vertebral segments at adjacent levels. Such alterations may accelerate degenerative changes in the vertebrae, ligaments and intervertebral disks

References

- Hibbs RA. An operation for progressive spinal deformities. NY Med J. 1911;93:1013-1016.
- Young PM, Berquist TH, Bancroft LW, Peterson JJ. Complications of spinal instrumentation. Radiographics. 2007;27:775-789.
- Rutherford EE, Tarplett LJ, Davies EM, Harley JM, King LJ. Lumbar spine fusion and stabilization: hardware, techniques, and imaging appearances. Radiographics. 2007;27:1737-1749.
- Slone RM, McEnery KW, Bridwell KH, Montgomery WJ. Fixation techniques and instrumentation used in the thoracic, lumbar, and lumbosacral spine. Radiol Clin North Am. 1995;33:233-265.
- Slone RM, McEnery KW, Bridwell KH, Montgomery WJ. Fixation techniques and instrumentation used in the cervical spine. Radiol Clin North Am. 1995;33:213-232.
- Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine (Phila Pa 1976). 1983;8:817-831.

References

- Frelinghuysen P, Huang RC, Girardi FP, Cammisa FP. Lumbar total disc replacement part I: rationale, biomechanics, and implant types. *Orthop Clin North Am.* 2005;36:293-299.
- Min JH, Jang JS, Jung B, Lee HY, Choi WC, Shim CS, Choi G, Lee SH. The clinical characteristics and risk factors for the adjacent segment degeneration in instrumented lumbar fusion. *J Spinal Disord Tech.* 2008;21:305-309.
- Slone RM, MacMillan M, Montgomery WJ. Spinal fixation. Part 3. Complications of spinal instrumentation. *Radiographics.* 1993;13:797-816.
- Watzke O, Kalender WA. A pragmatic approach to metal artifact reduction in CT: merging of metal artifact reduced images. *Eur Radiol.* 2004;14:849-856.
- Lee MJ, Kim S, Lee SA, Song HT, Huh YM, Kim DH, Han SH, Suh JS. Overcoming artifacts from metallic orthopedic implants at high-field-strength MR imaging and multi-detector CT. *Radiographics.* 2007;27:791-803.
- Stradiotti P, Curti A, Castellazzi G, Zerbi A. Metal-related artifacts in instrumented spine. Techniques for reducing artifacts in CT and MRI: state of the art. *Eur Spine J.* 2009;18 Suppl 1:102-108.

References

- Jinkins JR, Van Goethem JW. The postsurgical lumbosacral spine. Magnetic resonance imaging evaluation following intervertebral disk surgery, surgical decompression, intervertebral bony fusion, and spinal instrumentation. *Radiol Clin North Am.* 2001;39:1-29.
- Van Goethem JW, Parizel PM, Jinkins JR. Review article: MRI of the postoperative lumbar spine. *Neuroradiology.* 2002;44:723-739.
- Tartaglino LM, Flanders AE, Vinitzki S, Friedman DP. Metallic artifacts on MR images of the postoperative spine: reduction with fast spin-echo techniques. *Radiology.* 1994;190:565-569.
- Palestro CJ, Love C, Tronco GG, Tomas MB. Role of radionuclide imaging in the diagnosis of postoperative infection. *Radiographics.* 2000;20:1649-1660; discussion 1660-1663.
- Nouh RN. Spinal fusion-hardware construct: Basic concepts and imaging review. *World J Radiol.* 2012 May 28; 4(5): 193-207.

References

- Williams AL, Gornet, Burkus JK. CT Evaluation of Lumbar Interbody Fusion. AJNR Am J Neuroradiol 26:2057-2066.
- Hayashi D, Roemer FW, Mian A, Gharaibeh M, Muller B, Guermazi, A. Imaging Features of Postoperative Complications After Spinal Surgery and Instrumentation. AJR 2012;199:W123-129.